Mines and Minerals Branch Report of Activities 1988, Part A

D.R. MacDonald
and Y. Brown,
Editors

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Mines and Energy

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FOREWORD

On behalf of the Nova Scotia Department of Mines and Energy it is my pleasure to welcome you to the 1988 Open House and Review of Activities. This event provides an excellent opportunity for my staff to present to representatives of the mineral industry and the general public an overview of departmental activities in the area of earth science and mineral resources.

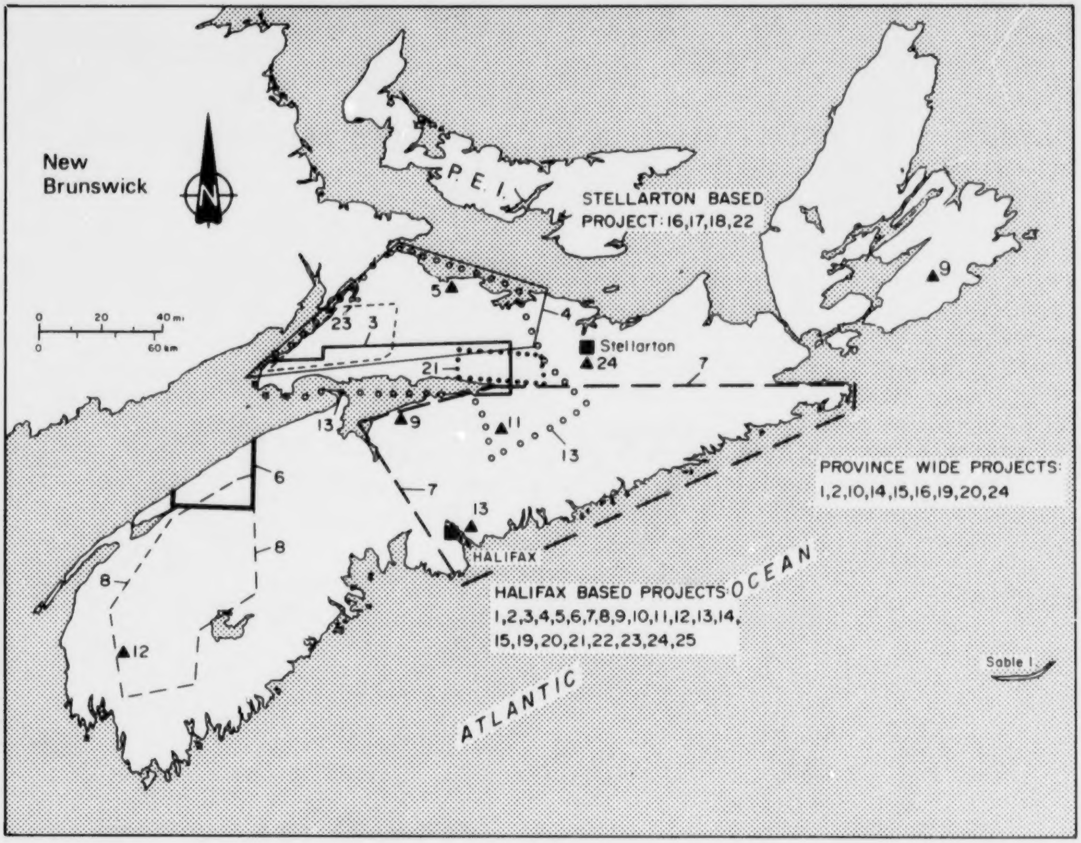
This publication provides brief summaries of all major programs and presents preliminary results where possible. These programs, collectively designed to evaluate and promote the development of Nova Scotia's mineral resources, involve staff from both the Mines and Minerals and Energy Branches of the Department, as well as members of the local academic community who are involved in joint research. Most importantly, the Open House provides an opportunity to highlight activities undertaken as part of the Canada - Nova Scotia Mineral Development Agreement which has been in place since June of 1984. We welcome, therefore, the participation of Energy, Mines and Resources Canada in our Open House again in 1988.

Nova Scotia has experienced a dramatic increase in activity in the mineral sector, driven largely by renewed interest in gold. In 1988, we are on the verge of several new developments with a number of deposits in the advanced exploration stages. We welcome the re-emergence of metals as a significant component of our mineral production. Equally significant, however, are new developments in the field of industrial minerals and coal, certain indications that our traditional mineral industry is alive and well.

Representations of the mineral industry have expressed support for the role of Mineral Development Agreements in fostering economic growth in the mineral sector. We share this conviction, and look forward to continuing progress through mutual consideration of our respective priorities and a growing spirit of co-operation. The programs displayed at our Open House bear witness to this collaborative effort.

Ken Streatch

Honourable Ken Streatch
Minister of Mines and Energy


New Brunswick
P.E.I.
STELLARTON BASED PROJECT: 16,17,18,22
0 20 40 mi
0 60 km
5
4
23 3
Stellarton
24
21
7
13
9
11
13
9
6
7
13
HALIFAX
8
8
12
PROVINCE WIDE PROJECTS: 1,2,10,14,15,16,19,20,24
HALIFAX BASED PROJECTS: 1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,19,20,21,22,23,24,25
ATLANTIC OCEAN
Sable I.

NOVA SCOTIA DEPARTMENT OF MINES AND ENERGY PROJECTS 1988

Mineral Resources Division

1. Regional Reconnaissance Geochemical Project *
2. Geochemical Atlas Project *
3. Catchment Basin Geochemical Study of the Cobequid Highlands *
4. Cumberland Basin Project *
5. Pugwash Salt Project *
6. Quaternary Mapping Project *
7. Meguma Gold Project *
8. South Mountain Batholith Project *
9. Base Metals Deposit Study *
10. Metallogenic and Tectonic Studies *
11. Stratigraphic Drilling in the Shubenacadie Basin *
12. East Kemptville Project *

Mineral Development Division

13. Aggregate Project *
14. Building Stone Project *
15. Gypsum and Anhydrite Project *
16. Various Commodities Project *
17. Core Library Project *
18. Mineral Exploration Monitoring/ Regional Office
19. Mineral Inventory Project *
20. Land Use Policy Development Project*

Energy Resources Division

21. Debert - Kemptown Basin Project
22. Stellarton Basin Project
23. Stellarton Basin Seismic Project, Coal Depositional/Sedimentological Study
24. Onshore Petroleum Source Rock Evatuation *
25. Offshore Petroleum Evaluation

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*Partial or complete funding from Canada - Nova Scotia Mineral Development Agreement

ONSHORE PETROLEUM ACTIVITY UPDATE

G. P. van Heuven

OIL AND GAS EXPLORATION RIGHTS MANAGEMENT

The Energy Resources Division is currently administering four onshore oil and gas exploration agreements (E.A.; Fig. 1). Each requires that certain minimum amounts of exploration be conducted on the agreement lands, including the drilling of a well. In addition, the agreement holders must pay annual rentals of 12 cents per hectare. Last year, annual E.A. rentals totalled $189,607.20 (Table 1).

On August 3, 1988, the Minister published a Call for Nominations pursuant to section 39 of the Petroleum Resources Regulations. This is the first such call ever held. It is designed to identify specific parcels of land the petroleum industry wished to have posted for competitive bidding through a Call for Exploration Proposals to be held later. The area around Alton, Colchester County, where a natural gas show occurred earlier this year during the drilling of a minerals borehole by the Department, has generated considerable interest.

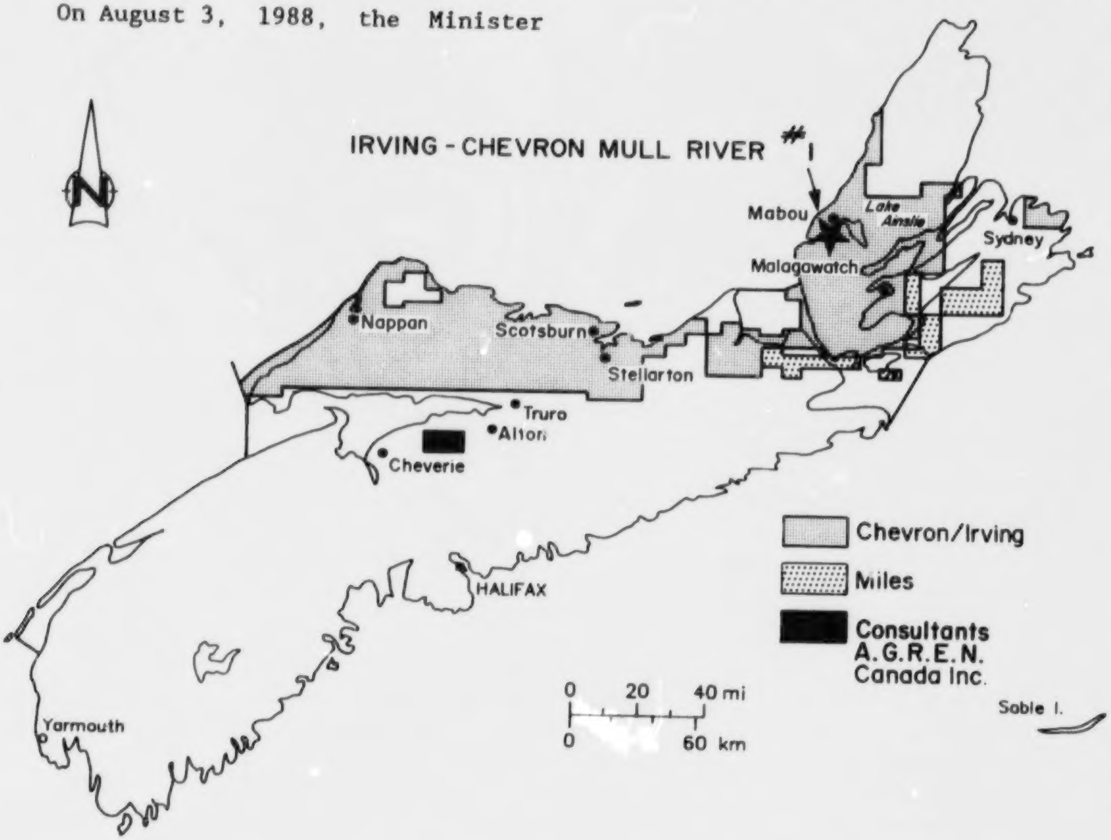
N
IRVING - CHEVRON MULL RIVER #1
Mabou
Lake Ainslie
Sydney
Malagawatch
Nappan
Scotsburn
Stellarton
Truro
Alton
Cheverie
HALIFAX
Yarmouth
Sable I.
Chevron/Irving
Miles
Consultants A.G.R.E.N. Canada Inc.
0 20 40 mi
0 60 km

Figure 1. Onshore exploration agreements under administration.

Table 1. Summary of Onshore Oil and Gas Rights Holders.

	Licensee	Negotiated Area (acres)	Negotiated Area (hectares)	Rentals Paid (1988)
	Chevron Canada Resources Ltd.			
1.	Cape Breton	1,469,743	594 805	$ 71,376.60
2.	Cumberland	2,066,382	836 265	100,351.80
3.	Miles	321,944	130 342	15,641.04
4.	Consultants A.G.R.E.N. Canada Inc.	46,780	18 648	2,237.76
	Total	3,904,849	1 580 060	$189,607.20

OIL AND GAS EXPLORATION ACTIVITY

Chevron drilled the Irving/Chevron Mull River #1 well near Lake Ainslie, Inverness County, on Exploration Agreement 860501-01 which is now held by Irving (75%) and Chevron (25%). The well was drilled to a total depth of 1502 m (4,927 ft.), tested and abandoned. By drilling the well, Chevron/Irving have satisfied the requirements of the Exploration Agreement work program and will be entitled to negotiate a three year renewal over approximately half of the 594 805 hectares currently held under this E.A.

COAL GAS

On December 1, 1987, Part III of the Petroleum Resources Regulations came into force. It provides for two types of agreements in respect of coal gas:

Coal Gas Exploration Agreement- Confers the right to explore for coal gas and the exclusive right to apply for a coal gas production agreement for specified lands. An annual rental of 12 cents per hectare is payable to the Province.

Coal Gas Production Agreement - Confers upon the lessee the exclusive right to produce coal gas from the subject lands for commercial purposes. The primary term of a coal gas production agreement may not exceed ten years. However, if coal gas is being produced commercially or if the lands are deemed capable of commercial production, the term will be extended. All coal gas produced under the authority of a coal gas production agreement is subject to a 5% royalty payable to the Province.

Both coal gas exploration agreements and coal gas production agreements are subject to provisions in the regulations designed to protect the holder of coal rights.

A coal gas agreement was signed on May 31, 1988, with the Cape Breton Development Corporation with a view to that company using coal gas to generate electricity for the Lingan Mine.

PETROLEUM SOURCE ROCK STUDY, ONSHORE NOVA SCOTIA: A PROGRESS SUMMARY[1]

P. G. McMahon

INTRODUCTION

The petroleum source rock study is a regional reconnaissance project designed to aid in the identification of regions within Nova Scotia that have the greatest potential for petroleum exploration. "Rocks that are, or may become, or have been able to generate petroleum are commonly called source rocks" (Tissot and Welte, 1984). The recognition and delineation of a petroleum source bed is dependent on the determination of its organic matter content, the organic type or quality and the evolutionary stage or thermal maturity of the organic matter.

METHODS

This study centres on organic geochemical analysis and includes compilation of previously reported data and acquisition of data obtained by a field sampling program. Analytical methods used have primarily been Rock-Eval pyrolysis and total organic carbon (TOC) analysis, and to a lesser extent vitrinite reflectance, thermal alteration index, elemental analysis and microscopic organic analysis. Approximately 370 field samples were collected to augment 700 sample data points compiled from previously reported analyses.

PRE-CARBONIFEROUS

The study has focused on Carboniferous rocks. Older organic material was found to be thermally post-mature with little hydrogen content remaining within the organic kerogen for petroleum generation and expulsion. Two exceptions to this are: (1) a small area of Silurian black marine shale of the Arisaig Group which although quite mature may have some gas potential and (2) another small area of Devonian black shale of the McAdam Lake Formation which may have a small gas generation potential (Fig. 1).

LOWER CARBONIFEROUS

The organic content of the Horton Group is found almost exclusively within lacustrine dark grey to black shale. When the analytical sample data were screened for a total organic carbon content in excess of 0.5% and a pyrolysis hydrocarbon (HC) yield (S_2) above 1.0 mg HC/g rock, two areas of the Horton Group were shown to have source quality beds: the Horton Bluff-Kennetcook area has a gas prone potential and the Big Marsh area has a strong oil and gas generating potential (Fig. 2). In addition to these areas, a sample from the North Branch Baddeck River indicates a hydrocarbon source potential from a varved lacustrine bed but the areal extent is presently unknown. A number of Horton Group samples from northern Cape Breton Island are presently being analyzed. Based on visual appearance they are relatively high in organic matter but they also appear to be thermally overmature.

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[1] Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

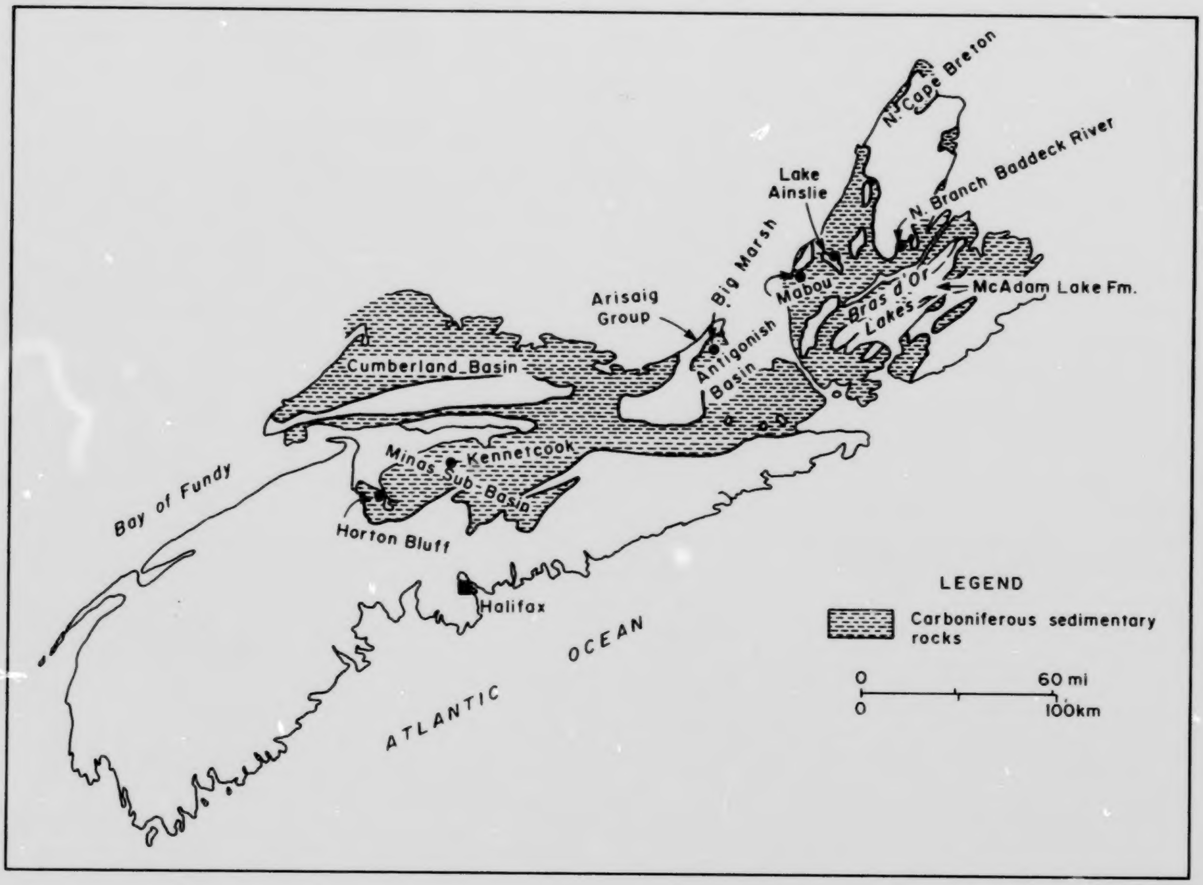
N. Cape Breton
N. Branch Baddeck River
Lake Ainslie
Big Marsh
Mabou
Bras d'Or Lakes
McAdam Lake Fm.
Arisaig Group
Antigonish Basin
Cumberland Basin
Kennetcook
Minas Sub-Basin
Bay of Fundy
Horton Bluff
Halifax
ATLANTIC OCEAN
LEGEND
Carboniferous sedimentary rocks
0
60 mi
0
100km

Figure 1. Study area location map outlining the extent of Carboniferous rocks in Nova Scotia.

Much of the data regarding the Windsor Group are still being analyzed but to date it has been shown that many of the carbonates are of source rock quality. Of particular interest is evidence of past hydrocarbon expulsion from some Windsor Group carbonates. For example some Shubenacadie Basin samples, as plotted on Figure 3, indicate prior petroleum generation and are therefore considered to be residual source rocks. The high organic carbon content (alginite, liptinite and liptodetrinite) would have certainly produced a much higher S_2 pyrolysis yield if these kerogens had not been previously depleted of available hydrogen by thermal cracking. The critical factor now being addressed is the ability of these expelled hydrocarbons (and gaseous derivatives) to have survived. Results indicate that in most areas the Windsor Group contains organic-rich carbonates. However, thermal maturation data show that some of the Windsor Group depositional basins are over-mature with respect to oil production and are therefore classified as gas prone areas. Data gathered to date strongly suggest that the most prospective regions are the Minas Sub-basin (of Bell, 1958), the Mabou-Lake Ainslie area and the west-central Bras d'Or Lakes area. Windsor Group rocks of the Antigonish and Cumberland Basins have not yet been fully assessed.

An interesting finding in the Mabou-Lake Ainslie area is that,

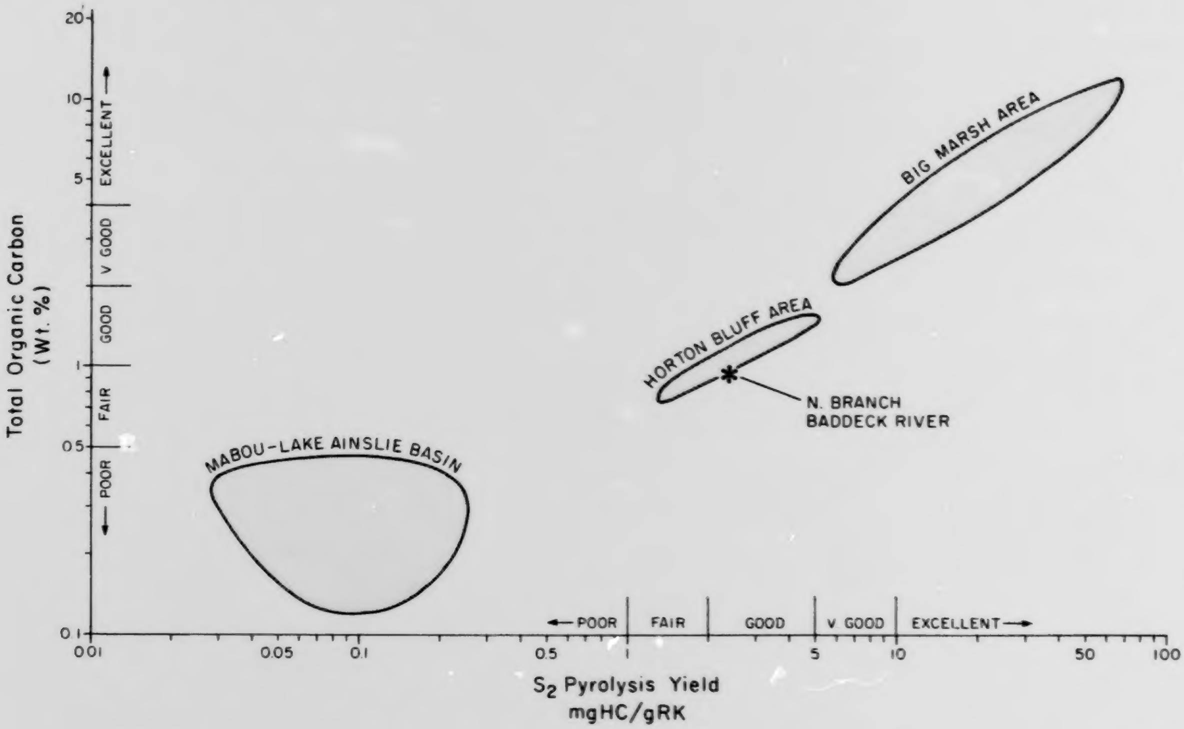

Figure 2. Log-log plot of total organic carbon content versus S_2 pyrolysis yield of Horton Group samples.

contrary to past exploration philosophies, the Strathlorne Formation grey shale facies of the Horton Group is not of source rock quality. Total organic carbon content is generally below 0.4% and pyrolysis hydrocarbon yields (S_2) are generally less than 0.18 mg/g rock (Fig. 2). On the other hand, a number of Windsor Group carbonate samples produced pyrolysis hydrocarbon yields (S_2) above 1 mg/g rock and total organic carbon contents above 0.4% (Fig. 3). It is generally accepted that marine carbonates require less total organic carbon than terrestrial sediments to be the source of equivalent amounts of hydrocarbons due to the higher hydrocarbon-generating potential of marine organic material (e.g. algae, bacteria, phytoplankton). As a result the quality scale on the left side of Figures 2 and 3 differ in their relationship to the total organic carbon content. It would appear, therefore, that the many oil shows documented within the upper Horton Group rocks in this area were derived from Windsor Group carbonates. Tectonic faulting facilitated the migration of oils from the younger marine carbonates (Windsor Group) to the older non-marine sediments (Horton Group). In fact, almost all hydrocarbon shows within the Horton Group are located very close to Windsor Group/Horton Group contact faults, particularly where the Horton Group has been up-thrown and juxtaposed with Windsor Group marine beds. This structural element is considered to be a major factor in hydrocarbon migration history within Carboniferous rocks throughout Nova Scotia. It has been found that many of the interpretations developed from specific areas are applicable to other Carboniferous areas within Nova Scotia.

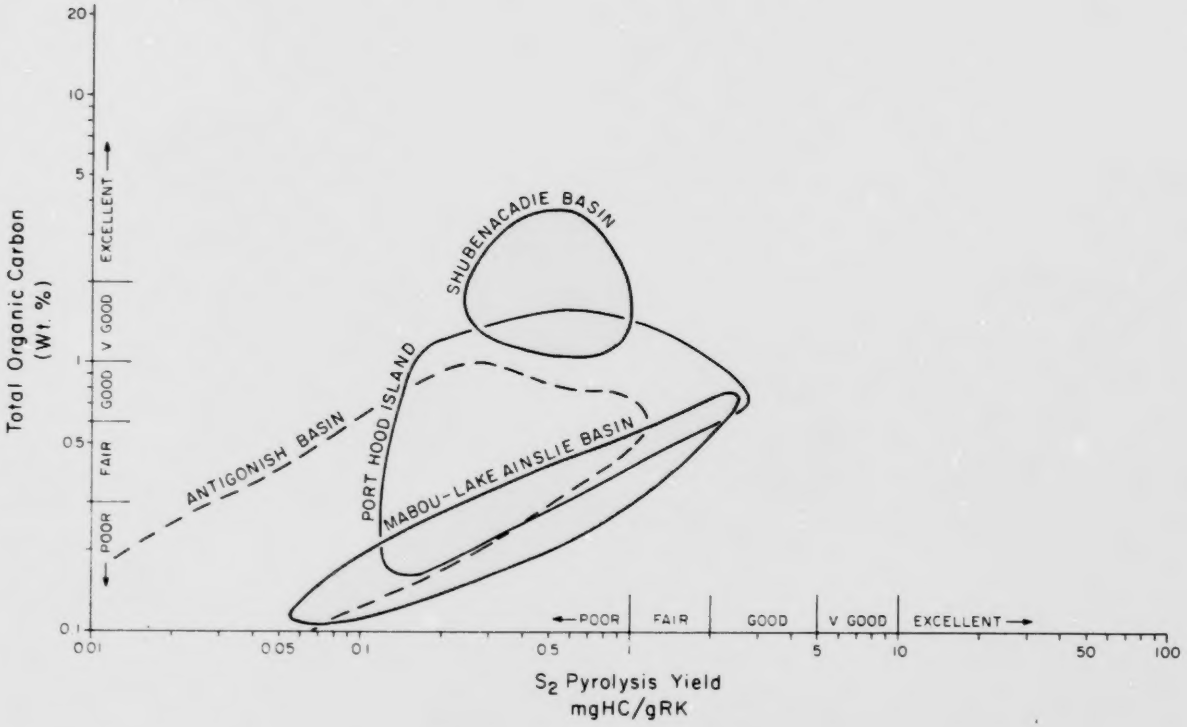

Figure 3. Log-log plot of total organic carbon content versus S_2 pyrolysis yield of Windsor Group samples.

UPPER CARBONIFEROUS

Upper Carboniferous rocks, dominated by terrestrial sediments, contain a number of high quality source rock sections for both oil and gas, particularly where these are rich in organic material derived from algal and bacterial sources. Work on these source rocks will be discussed at length in later, more detailed reports.

POST-CARBONIFEROUS

Triassic rocks of the Fundy Group were not investigated in detail due to the lack of exposed, or drill-intersected, organic-rich sediment. However, it has been proposed by a number of geologists that a deep lacustrine environment may have been present in the more central portion of the Triassic Fundy depositional basin, situated in the central part of the Bay of Fundy (Grierson et al., 1987; Brown, 1986).

Comparison of Figures 2 and 3 illustrates that the characterization of source rocks may be a useful tool in developing a more efficient exploration program. A final project report with maps detailing data and interpretations will be published by mid-1989.

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STRUCTURE AND CORRELATION OF COAL-BEARING STRATA OF THE ATHOL SYNCLINE, CUMBERLAND BASIN: RESULTS OF RECENT SEISMIC STUDIES[1]

J. H. Calder and D. S. Bromley[2]

During 1988, approximately 60 line-km of seismic data collected during the 1984 through 1987 field seasons were interpreted by the authors, shedding light on basin structures and on correlation of coal-bearing strata within the basin architecture. The program was successful in meeting the goals set out at the beginning of the 1984-89 Canada - Nova Scotia Mineral Development Agreement. The high resolution data provided important evidence regarding the correlation of major coal seams of the Joggins and Springhill coalfields. It has also led to the identification of major faults previously unrecognized within the basin. Finally, the seismic sections provide data on the geometry of Carboniferous strata from the Visean Windsor Group through to the Westphalian B - C Cumberland Group, all-important in basin analysis. This final topic, however, is beyond the scope of this report.

The results of the seismic program, including uninterpreted and interpreted profiles, are currently in preparation for publication, anticipated in 1989, as a paper of the Geological Survey of Canada. The paper will also address the implications of the project findings on coal exploration within the Cumberland Basin. The following is a brief summary of these results.

STRUCTURE

The Athol Syncline is host to the largest coal resource of mainland Nova Scotia (Calder et al., 1985), comprising both the Joggins and Springhill coalfields as well as the Salt Springs and Newville Lake occurrences. Determination of the structure of this region is therefore of primary importance to coal resource evaluation and exploration. The syncline was found to be asymmetrically folded with the steepest limb to the north, adjacent to the Minudie Anticline. Structural contours on the base of the Chignecto/Forty Brine horizon (Fig. 1) reveal minimal dip toward the axis, particularly in the east-central region of the Athol Syncline.

The trend of the synclinal axis within the mid-Cumberland Group is sinuous, ranging from northeasterly to easterly. The northeasterly axial trend at the eastern end of the syncline near Springhill Junction is an expression of steepening of both westerly-dipping strata of the Springhill coalfield and southerly-dipping strata of the Joggins-Chignecto coalfield. In the west half of the syncline the axis plunges to the west-southwest.

A major structural feature of the syncline is an easterly-trending fault

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[1] Funded by Nova Scotia Department of Mines and Energy and Geological Survey of Canada under the Canada - Nova Scotia Mineral Development Agreement

[2] Geological Survey of Canada, 601 Booth Street, Ottawa, Canada K1A 0E8

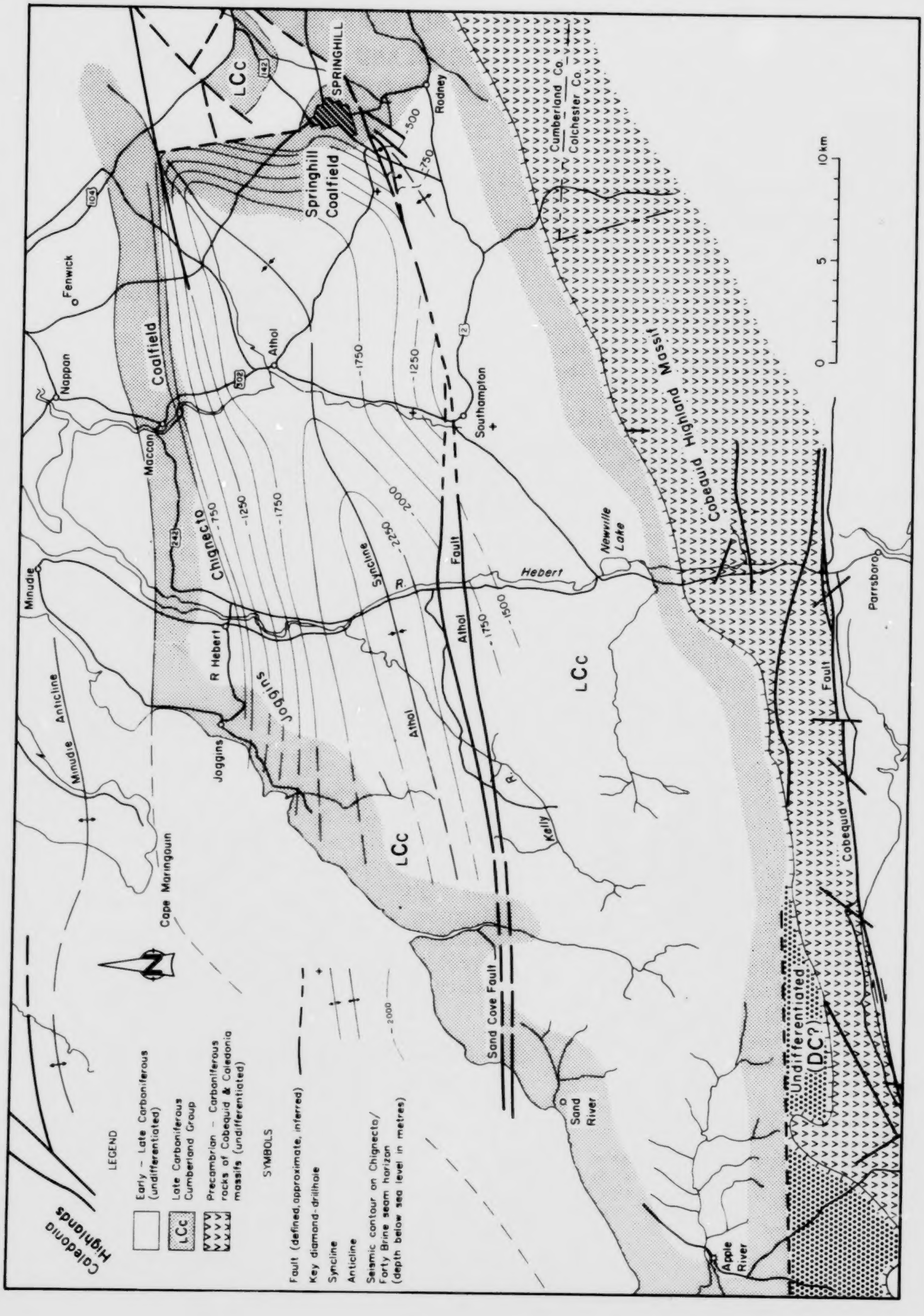
Caledonia Highlands
LEGEND
Early - Late Carboniferous (undifferentiated)
LCc Late Carboniferous Cumberland Group
Precambrian - Carboniferous rocks of Cobequid & Caledonia massifs (undifferentiated)
SYMBOLS
Fault (defined, approximate, inferred)
Key diamond-drillhole
Syncline
Anticline
Seismic contour on Chignecto/Forty Brine seam horizon (depth below sea level in metres)
2000
N
Cape Maringouin
Minudie Anticline
Minudie
R Hebert
Joggins
Joggins
Chignecto Coalfield
Maccan
Nappan
Fenwick
Athol
Springhill Coalfield
SPRINGHILL
LCc
Rodney
Southampton
Athol Syncline
Athol Fault
Sand Cove Fault
Hebert R.
Kelly R.
Newville Lake
LCc
Sand River
Apple River
Undifferentiated (DC?)
Cobequid Highland Massif
Cobequid Fault
Parrsboro
Cumberland Co.
Colchester Co.
104
302
242
142
2
-750
-1250
-1750
-2000
-2250
-1500
-500
0
5
10 km

Figure 1. Structure of the Athol Syncline, Cumberland Basin, based upon seismic event at or near the Chignecto/Forty Brine seam horizon.

zone near the present southern margin. This fault zone, here named the Athol Fault, is a high angle structure readily visible on lines 1002 and 1008 (line 1002 runs parallel to River Hebert, line 1008 at a right angle to the west). It is corroborated by slickensided shear planes in overlying outcrop on Kelley River and by erratic lithological/formational distribution near the Hebert River (A. Deal, personal communication). Projected eastward, the fault is coincident with similarly trending major faults subparallel to the Springhill Anticline. The Athol Fault projects westward to Sand Cove, where high angle extensional faults occur within a zone several hundred metres wide, named the Sand Cove Fault (R. J. Ryan, personal communication). If it is continuous with high angle faults at Sand Cove to the west and Springhill to the east, the Athol Fault may be between 50 and 100 km in length. The coal occurrence at Newville Lake lies south of this fault but may be truncated by it to the north.

The evidence cited above for the fault (zone) as a high angle structure is at odds with the interpretation by Grierson et al. (1987) of a layered flower structure involving Cobequid Highland 'basement' thrusts overlying the Carboniferous basin fill. This interpretation is based on Chevron Resources seismic data which are deeper than those collected under this program, but of lower resolution near surface.

Deformation of a lesser order of magnitude is represented by high angle to listric normal faults north and south of the synclinal axis between Fenwick and Springhill.

REGIONAL CORRELATION OF COAL HORIZONS

This 5 year project has provided valuable insight into the correlation of Springhill and Joggins coal seams. The high resolution data permit tracing of a reflecting event at or near a seam horizon virtually throughout the basin. The structure contour map (Fig. 1) depicts the configuration of one such horizon, the Chignecto/Forty Brine, which is effectively the base of coal occurrence in the Cumberland Group of past or present commercial viability.

Seam horizons were identified by projection to outcrop or in rare cases by tie-in to deep drillholes, however precise identification of coal seams is not possible. Due to the inevitable presence of faults of low magnitude dip displacement, and to inherent problems of projecting reflecting events to outcrop at the end of various lines, the picks are best considered a close approximation. Furthermore, the fact that horizons can be traced basin-wide does not necessarily imply that a coal seam persists over the entire area.

The general stratigraphic relationship between the Springhill and Joggins-Chignecto coal seams is depicted in Figure 2. The lower Springhill and upper Joggins seams are coeval based on the seismic correlation, with the No. 6 seam of Springhill near the horizon of the Joggins seam, and the Gesner seam near the Chignecto/Forty Brine horizons. The uppermost of the major Springhill seams (No. 2 through Rodney) correlate approximately with numerous thin seams described by Logan (1845) which outcrop south of McCarrons Creek on the Joggins shore. These correlations are corroborated by the chronostratigraphic record provided by miospore distribution (Dolby, 1987 and written communication, 1987).

These correlations have important implications for coal exploration within the Athol Syncline of the Cumberland Basin:

(1) The Joggins - No. 6 seams represent a basin-wide period of peat formation which resulted in the maximum

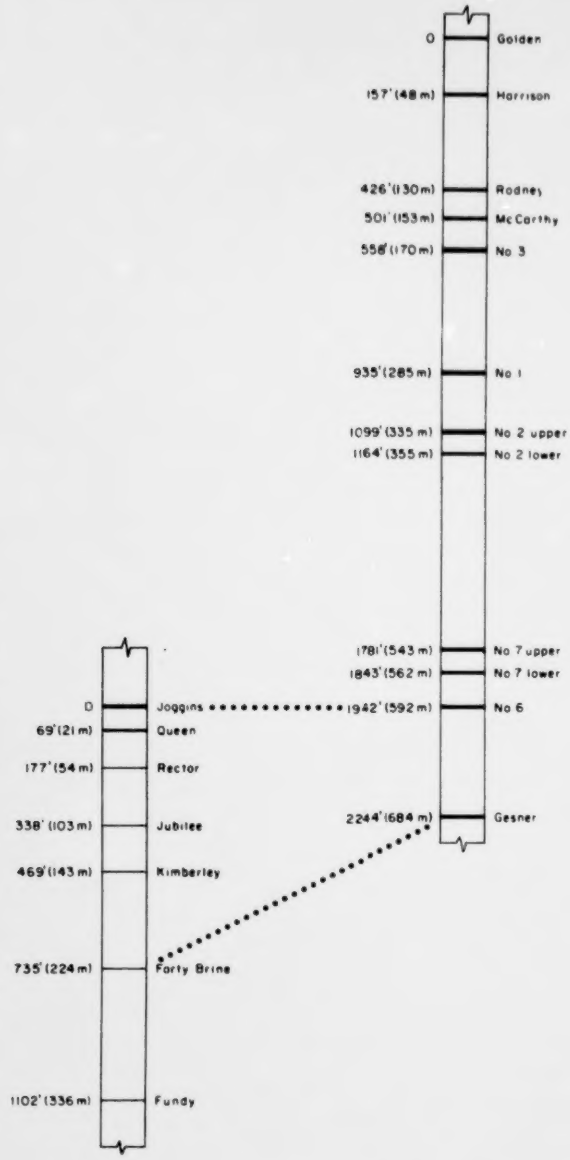
0
Golden
157'(48 m)
Harrison
426'(130m)
Rodney
501'(153m)
McCarthy
556'(170m)
No 3
935'(285m)
No 1
1099'(335 m)
No 2 upper
1164'(355 m)
No 2 lower
1781'(543 m)
No 7 upper
1843'(562 m)
No 7 lower
0
Joggins
1942'(592 m)
No 6
69'(21 m)
Queen
177'(54 m)
Rector
338'(103 m)
Jubilee
2244'(684 m)
Gesner
469'(143 m)
Kimberley
735'(224 m)
Forty Brine
1102'(336 m)
Fundy

Figure 2. Approximate correlation of Joggins (left) and Springhill (right) coal-bearing sequences based on Geological Survey of Canada seismic data.

areal distribution of coals within the basin;

(2) The coal seams of the Cumberland Group appear to exhibit a preferential change in location through time from the west (Joggins) to southeast (Springhill) with the upper Springhill coals continuing to progressively onlap alluvial sediments near the southern basin margin;

(3) If such a distribution holds true south of Joggins, the Newville Lake coal occurrence on the south side of the Athol Fault may be approximately equivalent to the highest Springhill seams (Rodney, etc.), onlapping basin margin conglomerates; and

(4) Although conditions of coal deposition at the time of the No. 2 seam were clearly optimal at the southeast of the basin, lesser, coeval peat mires nevertheless extended westward to the present day shore of Chignecto Bay at McCarron's Creek. This increases the potential for the down-dip extension of coal resources at Springhill into a significant part of the previously unexplored Athol Syncline.

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A PROGRESS REPORT ON THE DEBERT-KEMPTOWN BASIN PROJECT

R. D. Naylor and P M. Molyneaux

INTRODUCTION

The Nova Scotia Department of Mines and Energy is attempting to develop new models for coal exploration in the Debert-Kemptown Basin (Fig. 1). This comprehensive, long term project will ultimately involve detailed stratigraphic, structural and sedimentology studies as well as investigation of the petrography, quality and abundance of the basin's coals. The purpose of this report is to outline previous geological work in the basin and to make some general comments and observations on findings of the 1988 field season.

GEOLOGICAL MAPPING AND MINING HISTORY

Regional geological mapping of the Debert-Kemptown Basin has been undertaken by Fletcher (1891), Stevenson (1958) and Lortie (1979). Local mapping and(or) compilation of previous work has been undertaken by Keppie (1979), Donohoe and Wallace (1982) and Calder (1986). The sporadic and limited coal mining history of the Debert-Kemptown Basin has been summarized by Stevenson (1958) and Covert (1975).

STRUCTURE

Based on observations during the 1988 field season, the structural geology of the Debert-Kemptown Basin appears to be more complex than other coal-bearing basins in the Province. The strata of the basin are characterized by relatively abrupt changes in bedding attitudes in response to mesoscale faults and folds.

Fault styles observed to date include listric, high angle reverse, normal, dip slip and both sinistral and dextral strike slip. Mesoscale fault offsets are generally of the centimetre to less than 2 m scale. Small-scale folding within the basin is locally common. In some instances, these folds appear to be drag flexures associated with both meso- and large-scale faults. Accurate recognition and characterization of regionally significant meso- and larger scale structural elements will be a focus of future fieldwork.

STRATIGRAPHY

The Delaney Formation (Lortie, 1979) is the name informally applied to all strata within the Debert-Kemptown

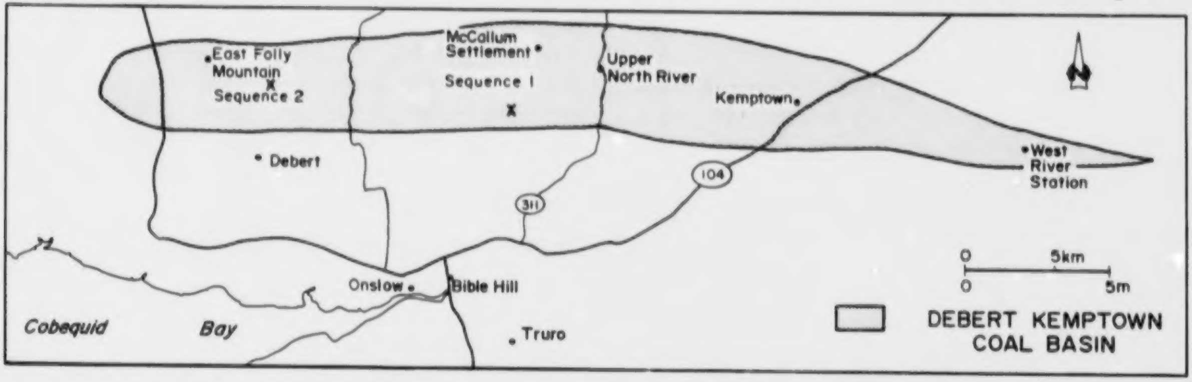

Figure 1. Location map of Debert-Kemptown Basin showing location of sequence 1 and 2.

Basin. The formation is subdivided into three members: the basal McCallum (grey conglomerate), the coal-bearing West Branch (grey and red mudrocks and sandstone) and the uppermost Debert (red and minor grey conglomerate, sandstone and mudrocks). Lortie (1979) provides no thickness estimates for the formation or any of the members. Palynological studies by Barss (reported by Donohoe and Wallace, 1982) suggest the Delaney Formation youngs from early Westphalian B in the south and east to Westphalian C in the west. The formation has been variously included in both the Cumberland and the Pictou Groups (e.g. Stevenson, 1958). It would appear however, as suggested by Calder (1986), that possible formal assignment of the Delaney Formation to an existing group (e.g. Cumberland, Pictou) awaits a more detailed regional stratigraphic study.

Mapping during the 1988 field season suggests that there is potential for significant refinement of the lithostratigraphic subdivision of the Delaney Formation. Previous workers, with the exception of Calder (1986), have provided only general descriptions of the sedimentology of the Delaney Formation. As a result Lortie (1979), in many instances, grouped thick stratigraphic sequences of contrasting lithologic character into the same formation.

Abrupt lithological changes of many stratigraphic sequences of the Delaney Formation are often accompanied by significant changes in bedding attitude, and(or) small-scale faulting. It is often difficult to determine, therefore, if these lithological changes are in response to stratigraphic or structural controls. Accurate determination of regional stratigraphy is therefore predicated on a clearer understanding of the regional structural framework.

SEDIMENTOLOGY

Calder's (1986) description of the sedimentology of selected sites within the Debert-Kemptown Basin provides a useful starting point for additional studies of the sedimentology of the Delaney Formation. Based on our recent work and that of Calder (1986), the rocks of the Delaney Formation exhibit a high degree of sedimentological variation. For example, Figure 2 illustrates significant differences in the sedimentology of two of the coal-bearing sequences of the Delaney Formation.

Sequence 1 is an outcrop section on the West Branch North River approximately 1 km north of the southern basin margin (Fig. 1). The sequence consists of clast supported, pale grey quartz granule conglomerate abruptly overlain by 0.50 m of impure coal with siltstone partings. The impure coal is overlain by a rooted sequence of organic-rich siltstone interbedded with pale grey, fine- to medium-grained, somewhat immature sandstone. The sequence is capped by 3 m of pale grey quartz granule conglomerate with both low and high angle cross-stratification.

Sequence 2 is a cored interval from 32.0 m to 49.9 m in drillhole DDNSD1 drilled by the Nova Scotia Department of Mines and Energy in 1975 (see Fig. 1). The 1.4 m thick coal seam at the base of this sequence is overlain by 5 m of grey claystone, which is in turn overlain by pale grey fine grained sandstone with thin mudrock interbeds.

A full discussion of the sedimentology of these sequences is beyond the scope of this report. It is worth noting, however, that Lortie (1979) included both these sequences in the West Branch Member.

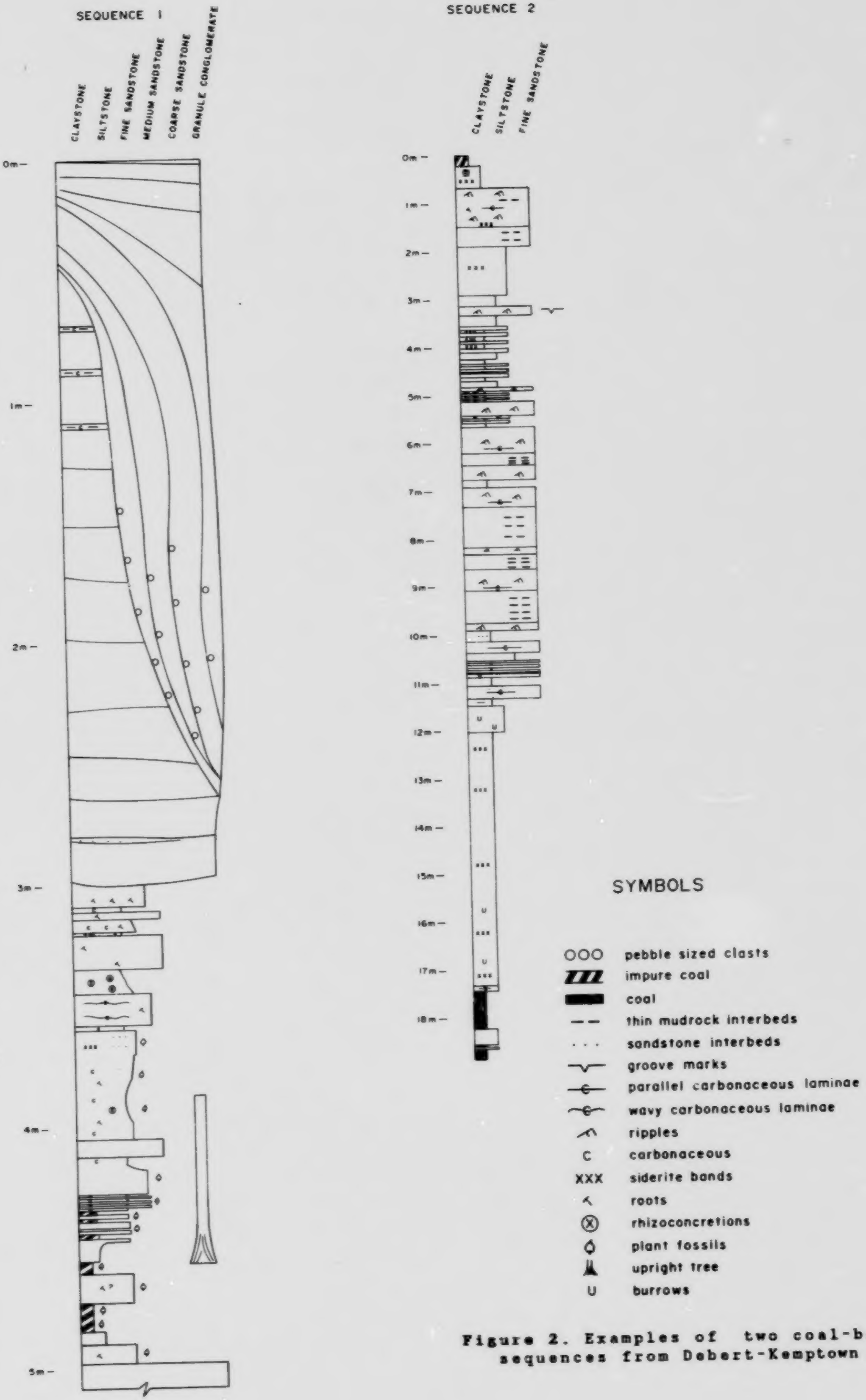
SEQUENCE 1
CLAYSTONE
SILTSTONE
FINE SANDSTONE
MEDIUM SANDSTONE
COARSE SANDSTONE
GRANULE CONGLOMERATE
0m
1m
2m
3m
4m
5m
SEQUENCE 2
CLAYSTONE
SILTSTONE
FINE SANDSTONE
0m
1m
2m
3m
4m
5m
6m
7m
8m
9m
10m
11m
12m
13m
14m
15m
16m
17m
18m
SYMBOLS
OOO pebble sized clasts
▨ impure coal
■ coal
— — thin mudrock interbeds
. . . sandstone interbeds
groove marks
parallel carbonaceous laminae
wavy carbonaceous laminae
ripples
C carbonaceous
XXX siderite bands
roots
⊗ rhizoconcretions
plant fossils
upright tree
U burrows

Figure 2. Examples of two coal-bearing sequences from Debert-Kemptown Basin.

COAL PETROGRAPHY, QUALITY AND ABUNDANCE

Petrographic studies of the Debert-Kemptown coals have been limited to vitrinite reflectance studies reported by Hacquebard and Donaldson (1970). To our knowledge, no maceral analysis studies of the coals have been reported. The vitrinite reflectance values (Ro) vary considerably between the coals of the Cottam Settlement area (Ro avg. .85) on the west side of the basin and those of the Kemptown area (Ro avg. 2.15) on the east side of the basin. The large differences in Rovalues between these areas may be resolved by a detailed regional study of both vitrinite reflectance and maceral abundance of the various coals. Sampling for this study was completed during the 1988 field season.

Stevenson (1958) provides useful information regarding coal quality within the basin. The best information on coal quality and abundance is contained in a report by Covert (1975) which describes the results of a 1975 drill program in the basin. The known coal seams within the basin vary from 0.01 - 1.83 m in thickness and have average ash and sulphur contents of less than 20% and 1.5% respectively.

An estimate of total coal resources in the Debert-Kemptown Basin is difficult at this time. Without a clearer understanding of the stratigraphy and structure it is impossible to estimate the number of seams which actually exist and their lateral extent.

COAL EXPLORATION POTENTIAL

The apparent structural complexity of the Debert-Kemptown coalfield is the biggest initial hindrance to effective coal exploration. The integrated approach being taken by the Nova Scotia Department of Mines and Energy should provide the information necessary to accurately assess the potential for successful coal exploration in this large mainland basin.

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STELLARTON BASIN PROJECT[1]

W. D. Smith, K. S. Gillis and S. A. Montgomery

INTRODUCTION

The Pennsylvanian coal resources of Bell's (1940) Stellarton Group, situated within the 120 km^2 Stellarton Basin (Fig. 1), have had a long history of mining activity (1825 - present, Calder et al., 1985). Mining today consists only of the recovery of pillars from pre-existing mines, however the area is attracting renewed interest as a source of low sulphur coal. The coal (sulphur contents of 0.7 - 1.7%, Wright and Townsend, 1974) is being considered for coal-fired electric power plants in order to help those plants meet the 1992 emission guidelines. A revival of large-scale underground mining activity is expected given Curragh-Westray's decision to proceed with exploitation of the Foord seam (Fig. 2).

In 1988 a project incorporating mapping and stratigraphic analysis of the strata of the west half of the basin was initiated. Data from this project will be used to produce a detailed geological map (scale 1:5000) and reports on the stratigraphy and paleogeography of the Stellarton Group. The geological map, in conjunction with the map of the east half of the basin (NSDME OFM 86-047, Naylor et al., 1988), will provide up-to-date coverage of the basin (Fig. 1b). The maps and reports will benefit the development and future exploration of the area's coal resources.

RESULTS

All of the strata exposed along the rivers, brooks, roads and in pits within the 40 km^2 map area were measured and described this past field season. A preliminary list of observed lithofacies of the Stellarton Group is presented in Table 1.

In the west end of the map area strata assigned to the Coal Brook Member by Bell (1940) comprise mainly coarse grained lithofacies (Sh, St, Si, Fi and minor Gc) interbedded with abundant coaly shale, thin banded coal and carbonaceous shale. Intense rooting, preserved as rhizoconcretions, is ubiquitous. Red bed zones (4-10 m thick), representing the Plymouth Member (Bell, 1940), interfinger with the Coal Brook Member to the level of the McLeod seam and locally, as in drillhole AP390 (Fig. 3), comprise 12% of the McLeod to Foord seam section. In the east end of the map area the Coal Brook equivalent strata comprise a predominantly fine grained, oil shale- and claystone-rich sequence. The sequence is comparable to the Coal Brook strata exposed in the east half of the basin described by Naylor and Smith (1986a, b) and mapped by Naylor et al. (1988). The eastern Coal Brook strata have been found, through drilling, to develop a greater number and thickness of sandstone bodies and more abundant rooted zones below oil shales toward the eastern basin margin (drillhole P59A, Naylor and Smith, 1988). The association of clastics-

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[1] Funded by Energy, Mines and Resources under the Canada - Nova Scotia Mineral Development Agreement

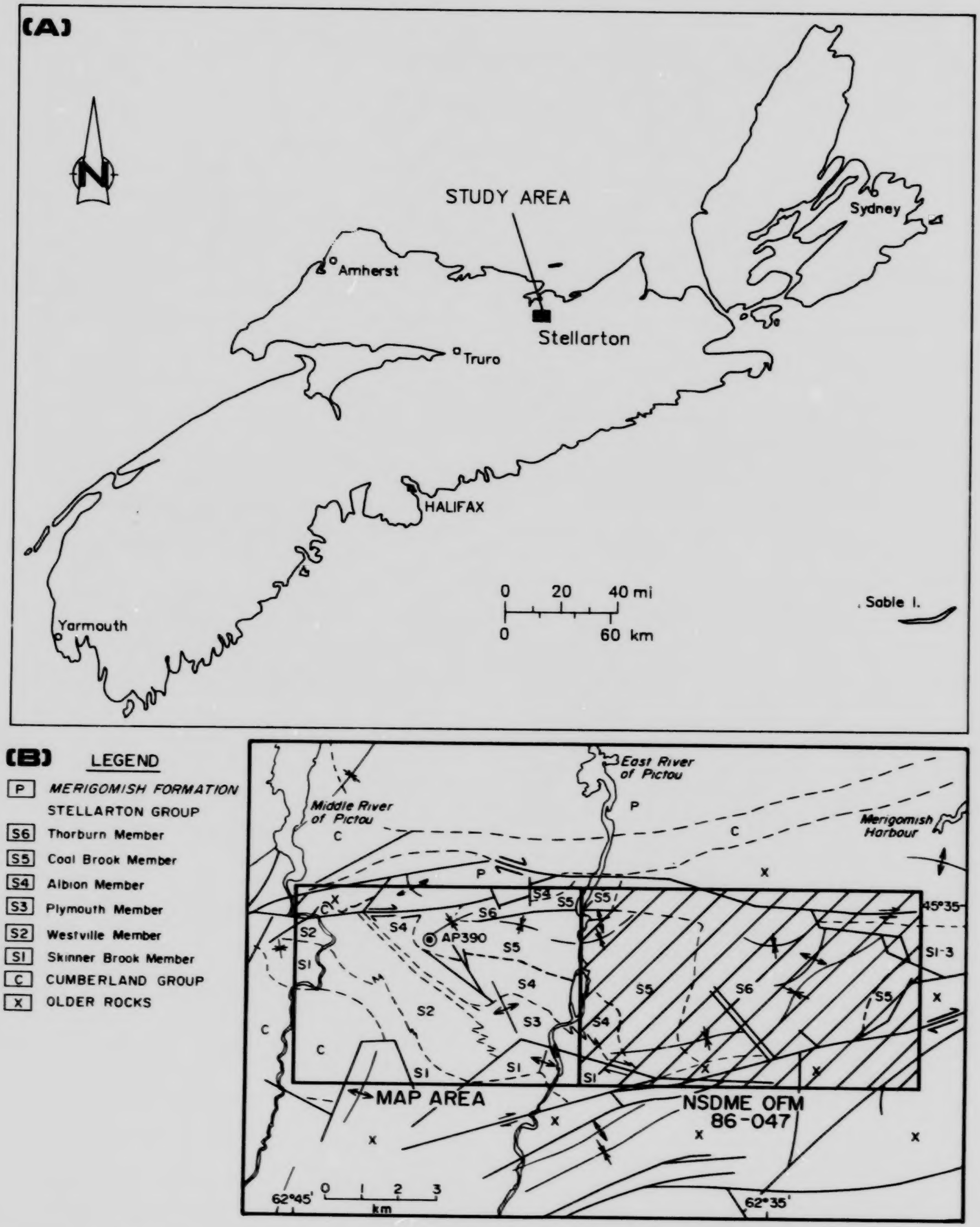
(A)
N
STUDY AREA
Amherst
Stellarton
Truro
Sydney
HALIFAX
Yarmouth
Sable I.
0 20 40 mi
0 60 km
(B)
LEGEND
P MERIGOMISH FORMATION
STELLARTON GROUP
S6 Thorburn Member
S5 Coal Brook Member
S4 Albion Member
S3 Plymouth Member
S2 Westville Member
S1 Skinner Brook Member
C CUMBERLAND GROUP
X OLDER ROCKS
East River of Pictou
Middle River of Pictou
Merigomish Harbour
AP390
MAP AREA
NSDME OFM 86-047
45°35'
62°45'
62°35'
0 1 2 3 km

Figure 1. Project area location maps. (a) Location of study area. (b) Stratigraphy and structural geology of the Stellarton Basin (after Yeo and Ruixiang, 1986) with the map area outlined and showing the location of drillhole section AP390 illustrated in Figure 3.

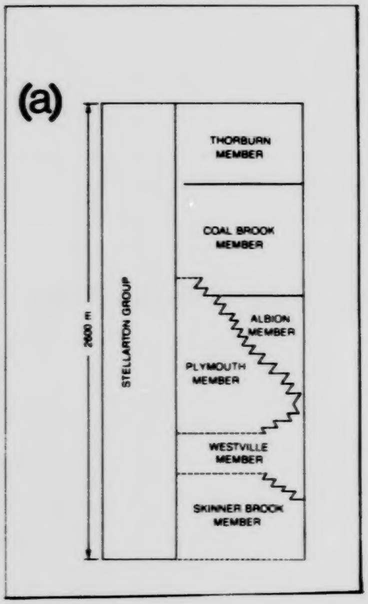

Figure 2a. Stratigraphy of the Stellarton Group. Bell (1940) subdivided the 2600 m thick Stellarton Group into two divisions with three members each. The upper division (Division II) consists of the intermediate Coal Brook Member (comprised of up to 60% oil shale) lying between the coal- and oil shale-bearing Thorburn Member, above, and Albion Member, below. The lower division (Division I) consists of a grey coal- and oil shale-bearing member (Westville) intermediate between two red-bed members: the Plymouth, above, and Skinner Brook, below. Contacts between members of Division I are diachronous.

coal-coaly shale sequences near the east and west basin margins and oil shale-claystone sequences in central basin areas suggests that lithofacies variation within the member was due to simultaneous deposition under fluvial-swamp (clastics, coal) and lacustrine (oil shale, claystone) settings during Coal Brook time.

Strata assigned to the Albion and Westville Members (Bell, 1940) also interfinger with the Plymouth Member and contain abundant oil shale. Within the Albion Member the oil shale is typically associated with coal and coaly shale. The oil shale, coal and coaly shale locally comprise organic-rich sections up to 200 m thick. Some of these oil shales contain fluorescing algal bodies (telalginite) which are lacustrine in origin (Hutton et al., 1980). The presence of the algal-bearing oil shale units suggests that a swamp environment bordering a lacustrine setting was the depositional environment of the Albion strata.

Oil shale beds were reported within the Albion and Westville Members (Naylor and Smith, 1986a) below the 45 numbered oil shale beds recognized by Naylor and Smith (1986b). In this study, an additional 15 beds, units 46 to 60, have been recognized below oil shale unit 45 (Fig. 2). The lateral continuity of units 1-45 have made them useful for correlation and as tools for coal exploration (Naylor et al., 1986). The lower oil shales can be traced for up to 2 km and may also be useful stratigraphic markers.

The Westville Member also gradationally interfingers downward and toward basin margins with the basal Stellarton Group strata, the Skinner Brook Member (Bell, 1940). The Skinner Brook Member generally comprises a red and mottled red and green-grey sequence of sandstone, siltstone and shale/mudstone and is interpreted as a basin margin alluvial plain deposit (Yeo and Ruixiang, 1987).

Minor thin interbeds of black coaly shale and locally abundant carbonaceous debris occur within the Skinner Brook Member at the extreme western end of the map area. These organic-rich zones probably represent fingers of the Westville Member stratigraphically below the level of known economic coal (i.e. Third and Fourth seams, Fig. 2). Environmental conditions under which the Westville Member was deposited favoured the accumulation of peat and subsequent formation of coal. Therefore, the organic-rich horizons within the

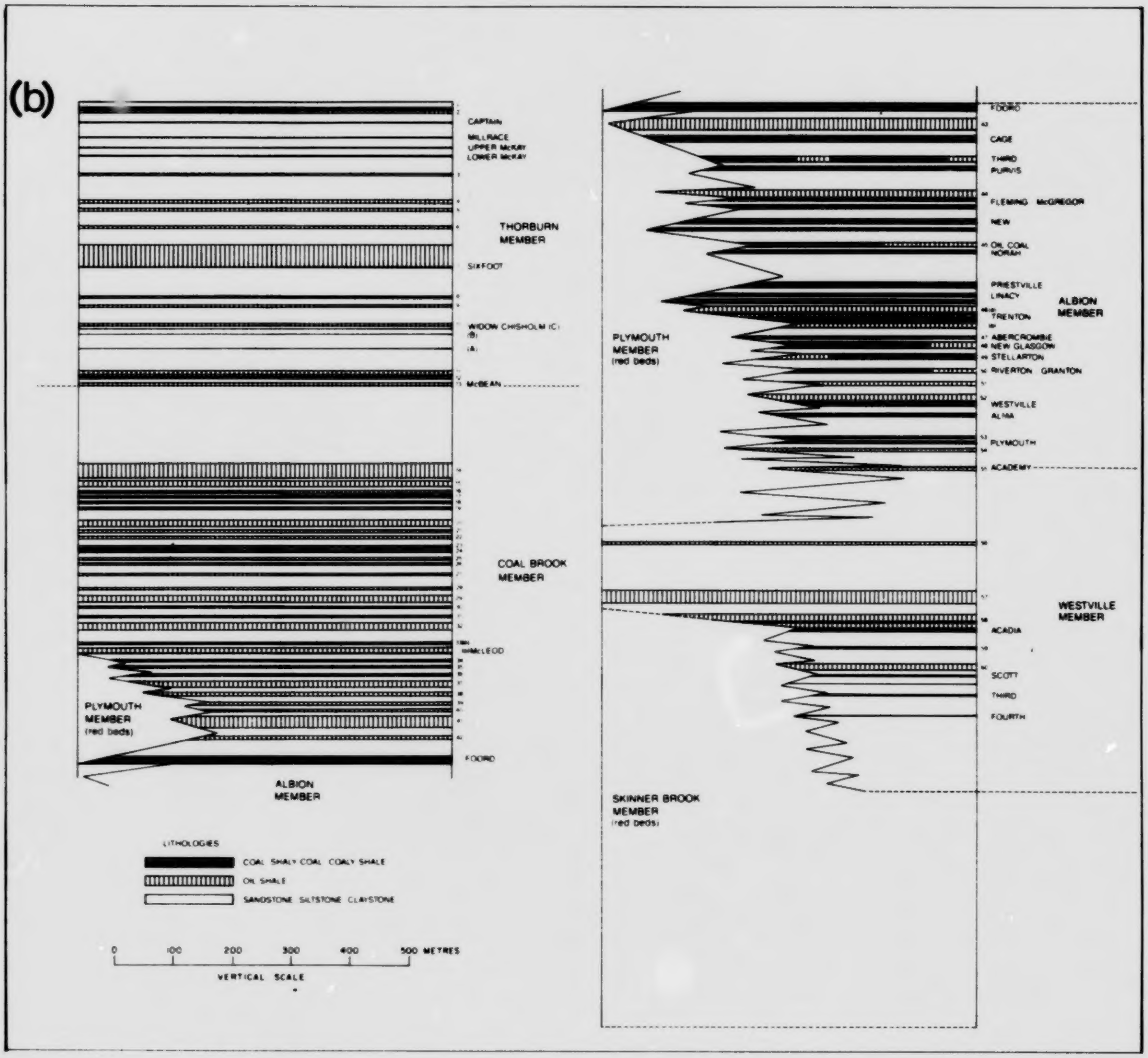
(b)
CAPTAIN
MILLRACE
UPPER McKAY
LOWER McKAY
THORBURN MEMBER
SIXFOOT
WIDOW CHISHOLM (C)
(B)
(A)
McBEAN
COAL BROOK MEMBER
McLEOD
PLYMOUTH MEMBER (red beds)
FOORD
ALBION MEMBER
LITHOLOGIES
COAL SHALY COAL COALY SHALE
OIL SHALE
SANDSTONE SILTSTONE CLAYSTONE
0
100
200
300
400
500 METRES
VERTICAL SCALE
FOORD
CAGE
THIRD
PURVIS
FLEMING McGREGOR
NEW
OIL COAL
NORAH
PRIESTVILLE
LINACY
TRENTON
ALBION MEMBER
ABERCROMBIE
NEW GLASGOW
STELLARTON
RIVERTON GRANTON
WESTVILLE
ALMA
PLYMOUTH
ACADEMY
PLYMOUTH MEMBER (red beds)
WESTVILLE MEMBER
ACADIA
SCOTT
THIRD
FOURTH
SKINNER BROOK MEMBER (red beds)

Figure 2b. Detailed stratigraphy of the Stellarton Group showing the location of oil shale units and coal seams. Stratigraphy from oil shale 1-45 inclusive after Naylor and Smith (1986a,b).

Skinner Brook sequence may develop into significant coal in basinward areas. Such areas are worthy of consideration as an exploration target.

FUTURE PLANS

The field data is currently being compiled onto the base map at a scale of 1:5000. A preliminary geological map of the Stellarton Basin (West Half) will be available in the fall of 1988. The duration of the project will include:

(1) additional study of drill core sections to evaluate the lateral variability and potential for coal

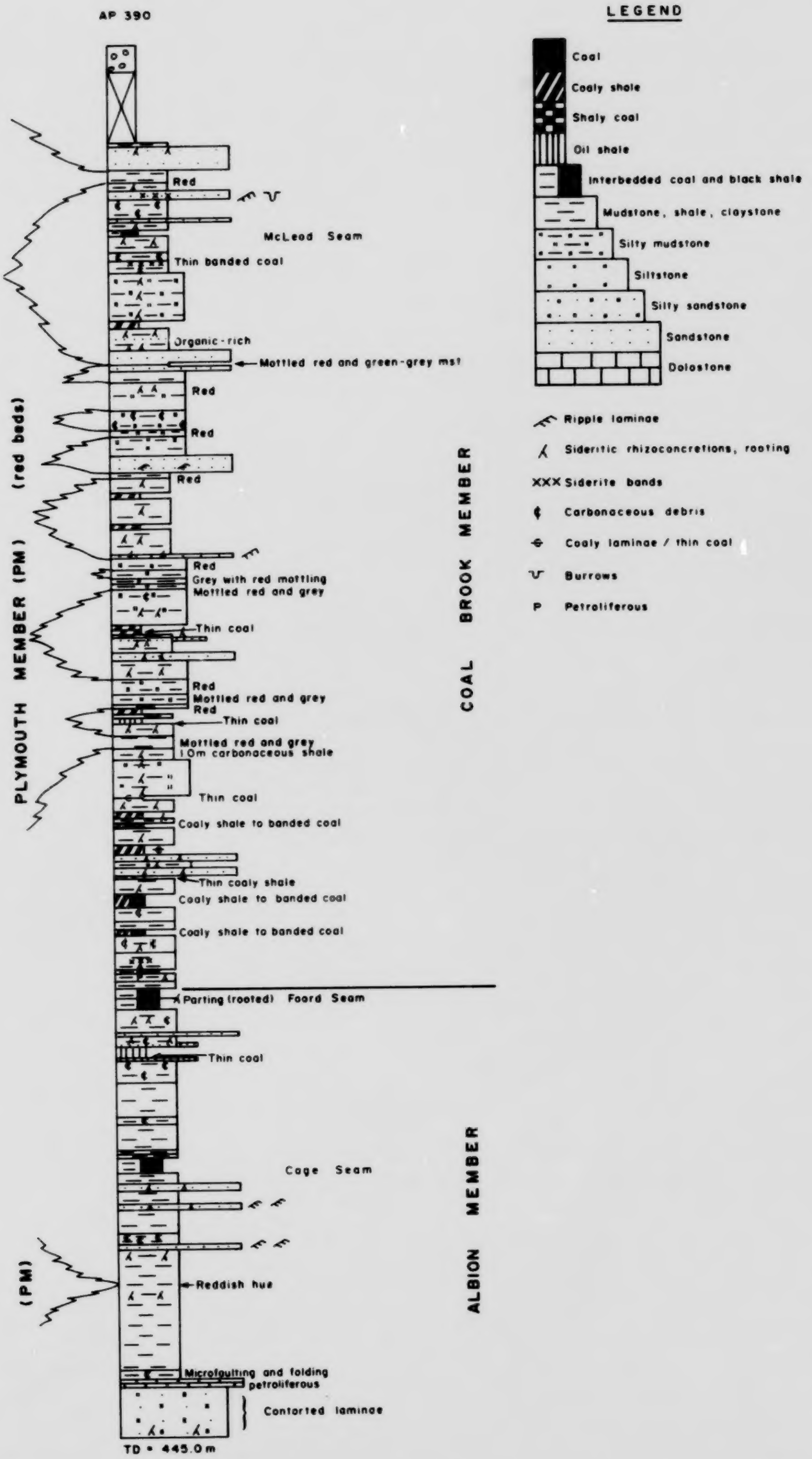
AP 390
Red
McLeod Seam
Thin banded coal
Organic-rich
Mottled red and green-grey mst
Red
Red
Red
Red
Grey with red mottling
Mottled red and grey
Thin coal
Red
Mottled red and grey
Red
Thin coal
Mottled red and grey
1.0m carbonaceous shale
Thin coal
Coaly shale to banded coal
Thin coaly shale
Coaly shale to banded coal
Coaly shale to banded coal
Parting (rooted) Foord Seam
Thin coal
Cage Seam
Reddish hue
Microfaulting and folding
petroliferous
Contorted laminae
TD = 445.0m
PLYMOUTH MEMBER (PM) (red beds)
COAL BROOK MEMBER
ALBION MEMBER
(PM)
LEGEND
Coal
Coaly shale
Shaly coal
Oil shale
Interbedded coal and black shale
Mudstone, shale, claystone
Silty mudstone
Siltstone
Silty sandstone
Sandstone
Dolostone
Ripple laminae
Sideritic rhizoconcretions, rooting
XXX Siderite bands
Carbonaceous debris
Coaly laminae / thin coal
Burrows
P Petroliferous

Figure 3. Drillhole section AP390, Stellarton Basin (West Half), Nova Scotia. TD = total depth. Drillhole location shown in Figure 1b.

Table 1. Lithofacies classification of the Stellarton Group in the west half of the Stellarton Basin (continued over).

LITHOFACIES CODE	LITHOLOGY	COLOUR	GRAINSIZE	SEDIMENTARY STRUCTURES AND/OR DIGNOSTIC PHYSICAL PROPERTIES	FOSSILS
Gc	Clast-supported conglomerate	pale grey	- pebble to cobble	- massive or trough cross-stratified - clast-supported - poorly developed normal grading - erosional bases, occasional (? wave) reworked ripple tops - minor interbeds of sandstones lenses	- rare transported trees
Gm	Matrix-supported conglomerate	pale grey	- mud to fine sand and pebble to cobble	- massive - matrix supported - poorly sorted angular clasts in a matrix of mud to fine sand	
Sm	Massive sandstone	pale grey to grey-brown	- fine to medium sand	- thickly bedded sandstone (10 cm thick beds average) - regular, even tops and bases - massive, non-laminated, structureless - stacked beds comprising up to 1-2 m thick sequence	- carbonaceous debris
Sh	Horizontally-bedded sandstone	pale grey to grey-brown	- very fine to coarse sand - occasionally pebbly sand	- often laminated with continuous/discontinuous parallel/wavy carbonaceous laminae - erosional bases with groove marks and occasional parting lineation - normal grading - thickly bedded (beds up to 35 cm thick)	- carbonaceous debris - occasional *Stigmaria sp.* - rare ostracods
St	Trough cross-bedded sandstone	greyish brown/ brownish grey	- very fine to coarse sand - occasionally pebbly	- individual beds (2-3 cm thick) have irregular, wavy tops and bases which pinch and swell laterally - sets of beds display a concave-up morphology exhibiting an erosional basal contact - channel lag; often of mudstone intraclasts - occasional siderite nodules	- carbonaceous debris and well preserved plant remains - *Stigmaria sp.* absent to common
Sr	Rippled sandstone	pale grey to brownish-grey /greyish-brown	- very fine to fine sand	- ripple cross lamination; often climbing - starved ripple lenses - ripple marks on bedding surfaces; straight- to undulatory-crested, continuous and discontinuous, symmetric and asymmetric - occasionally mudcracked	- carbonaceous debris - occasionally burrowed - rare to occasional gastropods - rare fish remains
Si	Interlaminated sandstone and siltstone	colour-banded pale grey and dark grey	- fine sand and silt; sand predominating	- thin bedded (less than 1 cm thick); flazer and lenticular - group of beds commonly form solitary or climbing ripples	- occasional burrows/ bioturbation - carbonaceous debris; sometimes abundant comprising organic-rich silty laminae
Fi	Interlaminated siltstone and sandstone	colour-banded dark grey and pale grey	- silt and fine sand; silt predominating	- thin bedded (less than 1 cm thick)	- carbonaceous debris; can be relatively organic-rich
Fm	Fm (silt): Massive siltstone	grey to dark grey	- silt	- massive, structureless - hard, cohesive - resistant to weathering - occasional siderite bands and nodules	- carbonaceous debris - occasional root traces - occasional well preserved plant fragments (*Cordaites sp.*, *Linopteris sp.*)
	Fm (clay): Massive claystone	bleached grey to pale grey and black	- clay to silty clay	- massive, structureless - blocky weathering - friable and non-cohesive (sticky/tacky) - often associated with or near to coaly horizons/coal seams	- intensely rooted commonly; often comprises an underlay - well preserved plant remains - carbonaceous debris

LITHOFACIES CODE	LITHOLOGY	COLOUR	GRAINSIZE	SEDIMENTARY STRUCTURES AND/OR DIGNOSTIC PHYSICAL PROPERTIES	FOSSILS
Fl	Laminated claystone or siltstone	colour-banded bleached grey and dark grey	- clay and silt	- couplets of bleached grey claystone and dark grey claystone bands or pale grey siltstone and dark grey claystone bands - claystone/siltstone bands are even, regular and laterally continuous; 1 mm to 2 cm thick - both normal grading and sharp contacts between bands - non-resistant to weathering	- rare plant fragments
Fc	Carbonaceous shale	dark grey	clay to silty clay	- fissile - non-resistant to weathering - pale grey powdery streak - occasional pale grey (silty) microlaminae - commonly micaceous - siderite nodules with pyritic core are common - commonly grades to Of or Fl	- plant fragments particularly Cordaites sp. Lepidostrobus sp.
Of	Fissile Oil Shale	dark grey to black; locally colour-banded dark grey and black	clay to silt	- fissile; non-laminated - waxy streak; light brown to dark brown in colour - planar to irregular fracture - non-resistant to weathering	- ostracods - pelecypods (Anthraconauta sp.) - fish remains (scales, fins, teeth) - fish fecal pellets - plant remains (Cordaites sp., Trigonocarpus sp.)
Om	Massive oil shale (Cannel shale)	black with a bluish or greasy lustre	clay to fine sand	- massive - hard, tough to break - conchoidal fracture style - waxy streak; dark brown to black - resistant to weathering - gives a distinctive "ring" when struck with a hammer - commonly associated with (mainly overlies) coal seams	- vitrainous coaly laminae - plant remains (Cordaites sp., Trigonocarpus sp.): pyritized and coalified - fish remains (scales, fins, teeth) - phosphatic fish fecal pellets
Os	Stellarite (Boghead Oil Shale)	brownish black	clay to fine sand	- powdery yellow brown streak - massive - may be internally slickensided or contorted - amber-coloured ellipsoidal grains (about 1 mm in diameter); abundant concentrations form thick bands and exhibit grading; bands fluoresce under UV-light	- fish remains (teeth, spines) - fecal pellets - plant remains
Cs	Coaly shale and shaly coal	black	clay and non-clastics (organic matter)	- interlaminated shale and coal : coaly shale-shale predominates over coal : shaly coal-coal predominates over shale	- coalified and pyritized plant remains (Cordaites sp., Lepidodendron sp.)
Cl	Coal; bright, bright-banded, bright and dull-banded, dull and bright-banded, dull	black	N/A; non-clastics: organic-matter	- microbanding	- coalified and pyritized plant remains (Cordaites sp., Lepidostrobus sp., Trigonocarpus sp.)
Db	Bedded dolostone	buff to tan	N/A; non-clastics: crystalline	- massive, structureless (2.5 m thick) - non-porous; tight - petroliferous odour when broken - restricted to Albion Member 65 m below Cage Seam	

Lithofacies comprising red-bed strata, Plymouth and Skinner Brook Members, are mainly Gm, Gc, Sm, Sh, St, Sr and Fm with minor interbeds of grey organic-rich beds (Fc and Cs).

development within the Coal Brook and Skinner Brook Members,

(2) documentation of the distribution, quality and depositional setting of the unexploited coals of the Albion and Westville Members and

(3) use of existing drillcore records, previous geological investigations and new field and core data to define the structure and facies distributions within the map area.

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COMPUTERIZATION OF COAL EXPLORATION DATA FOR NOVA SCOTIA[1]

J. D. Hughes[2], P. D. Watson[3] and D. J. MacNeil

SUMMARY

This co-operative project between the Geological Survey of Canada and the Nova Scotia Department of Mines and Energy entered its fourth year in 1988 under the Canada - Nova Scotia Mineral Development Agreement. All available coal geology and coal quality data from Nova Scotia's coalfields are being gathered, interpreted and entered into comprehensive computer databases. These data include information from boreholes in the form of geological logs and written descriptions, information from channel samples collected from underground workings, and also information from outcrop descriptions and bathymetric and topographic maps. The aim of the project is to integrate these data into comprehensive, verified models which can be used to answer a wide variety of questions about the geology and resource potential of Nova Scotia's coalfields. The reader is referred to Hughes, MacNeil and Watson (1986) for an outline of the rationale, procedures and objectives of the project.

Work to date has centered on building the databases, rather than on extensive interpretation of the data. From 1985 to 1987, available information from the Cumberland Basin, the Sydney Basin and other smaller coalfields of Cape Breton were entered and verified (Hughes, Watson and MacNeil, 1987). This information includes location and lithological data from 1170 boreholes totalling 127 785 m, similar data from over 2300 channel samples, and approximately 8700 coal quality analyses.

The construction of similar data files for the Pictou coalfield is continuing in 1988-89. Available data comprises 340 boreholes totalling 68 000 m and about 4200 coal sample analyses, some of which are already available in digital format. Four thousand channel samples and 300 outcrop samples from the Sydney coalfield are also being compiled.

APPLICATIONS

Preliminary work using the Sydney coalfield database has begun at the Institute of Sedimentary and Petroleum Geology in Calgary, Alberta. To test the success of integrating several topographic co-ordinate systems, posting maps have been generated to verify borehole and channel sample locations against regional topography in relation to the national 6° UTM co-ordinate base. Preliminary cross-sections and distribution profiles have been produced from data collected on the Hub, Harbour and Phalen coal seams.

Detailed geological interpretation and modelling will be conducted on the completed databases as part of the second phase of the Canada - Nova Scotia Mineral Development Agreement. This will allow the determination of the geological, environmental and resource quantity and quality characteristics of each coal seam in Nova Scotia.

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[1] Funded by Geological Survey of Canada under the Canada - Nova Scotia Mineral Development Agreement

[2] Geological Survey of Canada, Institute of Sedimentary and Petroleum Geology, Calgary, Alberta

[3] c/o Energy Resources Division, Nova Scotia Department of Mines and Energy, Halifax, Nova Scotia

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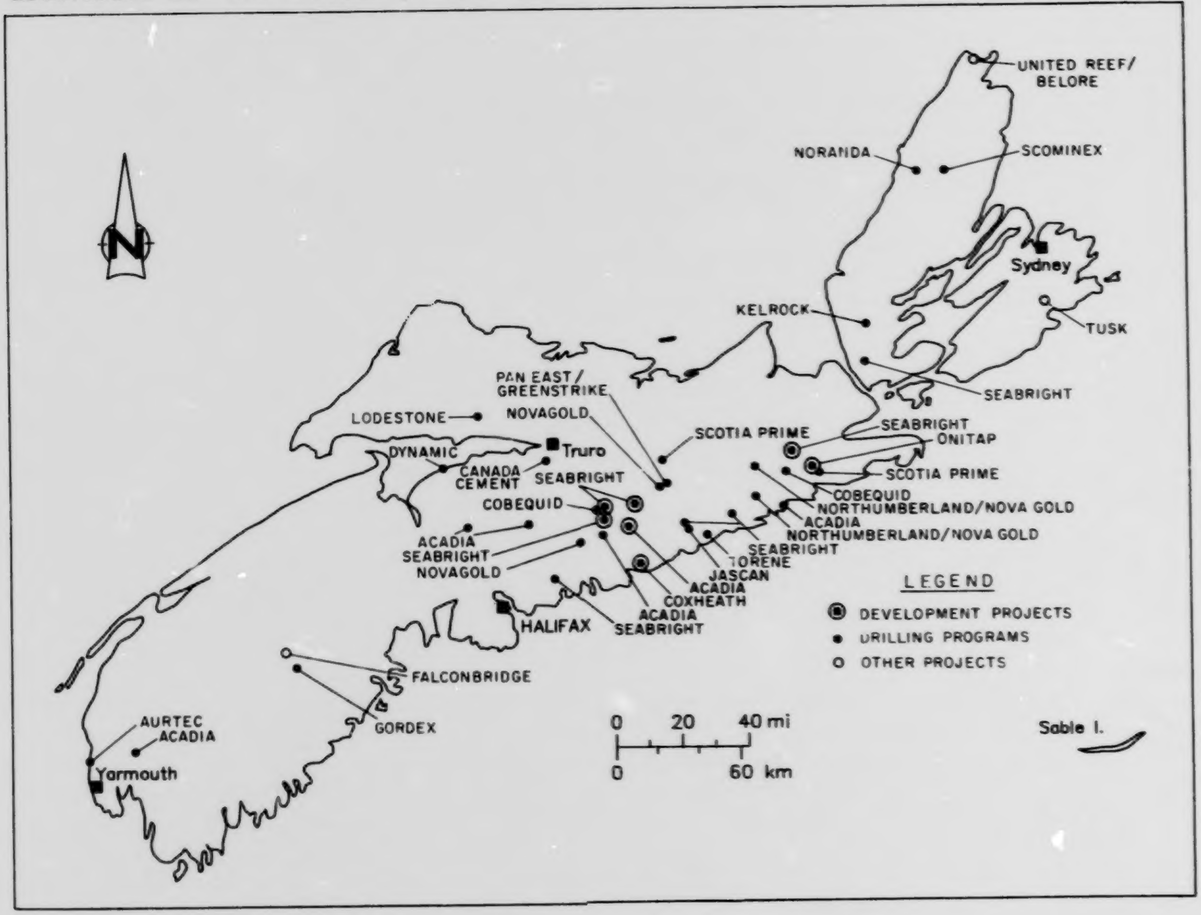
MINERAL EXPLORATION MONITORING

P. McCulloch

Mineral exploration in the Province (Fig. 1) during 1988 was down moderately from 1987, as revealed by a slowdown in activity during the second half of the year, but continued to maintain record expenditure levels compared with recent years. Exploration expenditures for 1988 are currently estimated at $30-35 million.

Exploration for gold continued to be the highlight of exploration activities in the Province, where continued interest in the historic gold mining districts contributed substantially to the record high of approximately $45 million recorded in 1987. Gold exploration has focused primarily on known gold occurrences hosted by Cambro-Ordovician metasedimentary rocks of the Meguma Group throughout southern mainland Nova Scotia and to a limited extent on Cambrian and Hadrynian rocks of northern mainland Nova Scotia and Cape Breton Island.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GREENSTRIKE
LODESTONE
NOVAGOLD
SCOTIA PRIME
SEABRIGHT
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NOVAGOLD
TORENE
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ACADIA
COXHEATH
ACADIA
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Figure 1. Location of principal exploration and development projects in Nova Scotia, 1988.

Exploration for industrial minerals including limestone, gypsum and several other commodities has shown a moderate increase in recent years as interest continues to grow in the industrial mineral sector. Exploration for limestone and gypsum accounted for the majority of exploration programs for industrial minerals in 1988 and continued at roughly the same level as 1987. Exploration for limestone and gypsum has been directed primarily at expanding current reserves by various industrial mineral producers in the Province and includes developing additional reserves on currently producing properties as well as developing new reserves in other areas. Exploration for base metals has remained at a low level of activity in comparison to gold with only a small number of projects completed in 1988.

Highlights of current exploration activity centre on the advanced exploration and development work completed on several gold properties in Halifax and Guysborough Counties. These include the Caribou, Fifteen Mile Stream, Moose River, Mooseland and Tangier gold properties in Halifax County and the Cochrane Hill, Forest Hill, Goldenville and Upper Seal Harbour gold properties in Guysborough County.

Westminer Canada Limited (Seabright Division) continued a detailed evaluation of the Forest Hill gold property during the year. The company completed additional underground diamond-drilling and bulk sampling at the Teasdale Mine and began underground bulk testing on the Kennedy zone, 1.8 km east of the mine site. Western Mining of Australia acquired the assets of Seabright Resources Incorporated, including the Forest Hill property, in a takeover at the beginning of the year. Under the direction of Westminer, Seabright Explorations Incorporated continued work on the Caribou and Moose River gold properties. Detailed underground mapping, sampling and diamond-drilling were completed at Caribou to assist in the evaluation of potential ore reserves at the Holman Mine. A development ramp was driven on the Moose River property, 2 km west of the village, to facilitate underground bulk sampling of drill-indicated ore reserves in the vicinity of the Dr. Sutherland shaft. Surface bulk sampling also started in the vicinity of the Touquoy mine property at Moose River to test a potential large tonnage, low grade ore zone outlined in recent drilling.

Hecla Mining Canada Limited, in a joint venture agreement with Acadia Mineral Ventures Limited, began a detailed underground exploration program at Mooseland to assess the drill-indicated ore reserves outlined in recent drilling. The company plans to complete a 360 m (1,180 ft.) shaft to facilitate bulk sampling on both the west zone in the vicinity of the old workings and the newly discovered east zone.

Coxheath Gold Holdings Limited continued the second phase of a detailed exploration and development program on the Tangier gold property during the year. Work included additional underground diamond-drilling and bulk sampling. The company also completed construction of a mill to process bulk sample material from the current program and to handle future mine production.

Northumberland Mines Limited completed an underground bulk sampling program on the Cochrane Hill gold property during the first half of the year. A decline was driven 100 m east of the Mitchell shaft to access drill-indicated ore beneath the open pit. The company also began detailed underground mapping, sampling and diamond-drilling on the Goldenville gold property during the year. The Cochrane Hill gold property was aquired along with the Goldenville gold property by Novagold Resources Incorporated in a recent takeover. Operations on the two properties were continued by Novagold.

Onitap Resources Incorporated and joint venture partner Orex Exploration Incorporated continued a detailed exploration program on the Upper Seal Harbour gold property near Goldboro. Surface drilling has been ongoing on the property and an underground bulk sampling program was started mid-year to test drill-indicated ore reserves below the old workings. The Boston-Richardson shaft is to be deepened to 275 m (900 ft.) to access the -245 m (800 ft.) level and a 610 m (2000 ft.) decline is being driven to a vertical depth of 125 m approximately 250 m west of the shaft.

Novagold Resources Incorporated continued surface drilling on the Fifteen Mile Stream gold property and carried out a surface bulk sampling program on the property to test several mineralized veins outlined in the drilling program.

DRILL CORE LIBRARY[1]

J. D. Langille

The Nova Scotia Department of Mines and Energy (NSDME) maintains core library/storage facilities at four locations in the Province. Two locations are in Stellarton, Pictou County (at the NSDME regional office on Bridge Avenue and in the Industrial Park on Acheron Court), one is in the Debert Air Industrial Park, Colchester County, and one is near Malagawatch, Inverness County.

The main core facility in the Stellarton Industrial Park was increased to four buildings during 1988 with the opening on April 25 of a new building with increased office and examination areas and additional storage area. The additional storage area has allowed initiation of a project to consolidate all Meguma Terrane core in one building for faster access. Also, smaller packages of core from the same area are being assembled in close proximity.

Throughout 1988, use of all facilities for examination and sampling of core continued on a high level by NSDME staff and industry, as well as academic and private individuals. Only the Stellarton facilities are in regular use and have equipment (e.g. core splitters, diamond saws, etc.) readily available.

Core library staff are permanently on hand in Stellarton only. As most core is stored on pallets and moved with a fork lift some prior notice (usually 24 hours) of a visit is appreciated. All visits outside the Stellarton area should be requested at least 48 hours in advance. For appointments telephone Jim Langille 752-4842 or John McMullin 752-8429.

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[1] Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

REPORT OF CORE LIBRARY ACTIVITIES[1]

W. Palmer

Work continued during 1988 on the core evaluation program initiated in 1985 under the Canada - Nova Scotia Mineral Development Agreement. A geologist, W. Palmer, and technician, J. O'Leary, continued to examine and evaluate diamond-drill core from selected areas in the Province where large amounts of core have been drilled. These evaluations will permit more effective selection and disposal of core in order to allow more efficient use of available core library space and provide additional information for core library users.

Since 1985 evaluations and reports have been completed on large volumes of core from the Getty-Gays River lead-zinc deposit (11 775 m, 38,631 ft.), the Walton barite-base metal deposit (12 633 m, 41,447 ft.) and the Meaghers Grant area (2713 m, 8901 ft.). During 1988 approximately 12 000 m (40,000 ft.) of core from the Kaiser celestite deposit located at Enon Lake were examined and evaluated. A report is presently being compiled.

Various trial criteria have been established by the drill core staff for the retention and disposal of core according to the classification of the drill core source (e.g. abandoned mine, mineral prospect, etc.). No large scale disposal of core has yet taken place, however recommendations for as much as 60% of the above core lots have been listed and made available in various reports. Disposal of core that has been identified through this process as being excess will be made after the reports have been circulated and discussed by a committee of appointed departmental representatives.

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[1] Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

INDUSTRIAL MINERALS[1]

J. H. Fowler

Nova Scotia has been producing and exporting industrial minerals for more than 200 years and the industry is internationally competitive in today's markets. It maximizes resource utilization and takes advantage of the Province's strategic geographical location and excellent marine shipping and overland transportation systems to access world markets.

In Nova Scotia there are 18 industrial mineral producers operating at 31 sites extracting 10 commodities including anhydrite, barite, clay, shale, dolomite, gypsum, limestone, peat moss, salt and silica sand. Nova Scotia also has a major aggregate industry operating in both granular and bedrock deposits.

Many of the commodities produced are shipped to markets in other regions of Canada, the United States, the Caribbean, western Europe, the Middle East and Japan. Unprocessed materials that are shipped include aggregates, salt and gypsum. Manufactured or processed materials that are shipped include pharmaceutical barite, cement, plaster of paris products, clay products, food and chemical grade salt and peat moss products.

The total value for industrial mineral production including secondary processing in 1987 was over $200 million. Direct employment in the industry totalled 1800.

Some of the more significant developments in 1987 include:

(1) an 86% increase in cement production over the previous year due to increased shipments to markets in Quebec and Ontario;

(2) an increase in exports of crushed stone, mainly to east coast and gulf coast ports in the United States;

(3) development of new markets for building bricks, in the New England region;

(4) production of over 1 million tonnes of gypsum from Nova Scotia quarries in 1987 and

(5) shipments of plaster of paris products to new markets in western Europe.

The global demand for industrial mineral commodities continues to increase and Nova Scotia has many of the industrial minerals currently in demand. In light of this, several programs designed to create an awareness of the Province's industrial mineral development potential have been carried out. Funding for these programs was provided under the Canada - Nova Scotia Mineral Development Argeement. Included are resource identification and evaluation projects, market studies, and resource promotion programs.

RESOURCE PROJECTS COMPLETED IN 1988

(1) *Diatomite Deposits of Nova Scotia* by A. R. Anderson. This report, which describes the diatomite deposits

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of Nova Scotia, will be available in late 1988.

(2) *Filler and Extender Minerals in Nova Scotia* by P. Luke. This study identifies deposits in Nova Scotia which have potential to produce filler grade products. The report will be available in late 1988.

RESOURCE EVALUATION PROJECTS IN PROGRESS

(1) A project to identify and promote the building stone resources of Nova Scotia.

(2) A program to document the gypsum and anhydrite resources of Nova Scotia and to promote new uses for these commodities.

(3) Aggregate resource mapping project in selected regions of Nova Scotia.

(4) An evaluation and information database compilation of the Province's lesser known industrial minerals.

These projects are described in this publication by the respective project managers.

MARKET AND RESOURCE PROMOTION STUDIES COMPLETED

OFR 88-013 *A study of U.S. East Coast Industrial Mineral Markets for New Brunswick, Newfoundland and Nova Scotia* by Metals Economics Group, 1988. Prepared for Mineral Policy Sector, Energy, Mines and Resources Canada, 286 pages.

OFR 88-039 *Marine Transport Study for Nova Scotia* by Leslie MacIntyre, Maritime Associated Inc., May 1988. Prepared for Mineral Policy Sector, Energy, Mines and Resources Canada, 38 pages.

OFR 88-040 *Aggregate Market Study for New Brunswick and Nova Scotia* by ADI Limited, Fredericton, New Brunswick, 1988. Prepared for Mineral Policy Sector, Energy, Mines and Resources Canada, 309 pages.

OFR 88-049 *Compilation of Information of Surficial Mineral Resources off Eastern Canada* by Earth and Ocean Research Limited, March, 1988. Prepared for Mineral Policy Sector, Energy, Mines and Resources Canada, volume 1, 352 pages; volume 2, appendices 4 to 21, 321 pages; volume 3, enclosures, 40 maps.

A study on underground storage capability of Nova Scotian salt deposits by Nolan Davis and Associates will be available in 1988. This study was prepared for Mineral Policy Sector, Energy, Mines and Resources Canada.

8th INDUSTRIAL MINERALS INTERNATIONAL CONGRESS

A delegation from the Nova Scotia Department of Mines and Energy attended the 8th Industrial Minerals International Congress in Boston, April 24-27, 1988. A paper, *Nova Scotia-North America's Doorstep to Industrial Mineral Opportunity* was presented by Dr. R. R. Potter, Assistant Deputy Minister, Nova Scotia Department of Mines and Energy. The presentation portrayed Nova Scotia as a world class industrial minerals producer and a province with many excellent resource development opportunities. Along with the presentation, the Department had a 6.6 m X 2.6 m display at the congress showing Nova Scotia's thriving industrial minerals industry and abundant resources which are well located (geographically) to access markets anywhere in the world.

International Industrial Minerals Congress meetings are excellent forums to publicize resource development opportunities and the Boston meeting was no exception. Registration numbered 666, mostly company representatives, from 37 countries.

Interest in Nova Scotia's industrial mineral resources was very high and the four industrial mineral project geologists also attending the congress did an excellent job of promoting the industrial mineral wealth of Nova Scotia.

NEW PUBLICATIONS

(1) *Industrial Mineral Mining in Nova Scotia.* This is a 20 page promotional booklet on the industrial mineral activities and resources development potential in Nova Scotia and was prepared for Mineral Policy Sector, Energy, Mines and Resources Canada.

(2) Nine industrial mineral commodity pamphlets were published in 1988 including:

Information Circular 12 - Building Stone in Nova Scotia by G. B. Dickie.

Information Circular 13 - Limestone and Dolomite in Nova Scotia by P. Luke and R. H. MacDonald.

Information Circular 14 - Silica in Nova Scotia by R. H. MacDonald.

Information Circular 15 - Barite, Celestite and Fluorite in Nova Scotia by J. H. Fowler.

Information Circular 16 - Gypsum and Anhydrite in Nova Scotia by G. C. Adams.

Information Circular 17 - Diatomite in Nova Scotia by A. R. Anderson.

Information Circular 18 - Peat Moss in Nova Scotia by A. R. Anderson.

Information Circular 19 - Salt in Nova Scotia by G. Prime.

Information Circular 20 - Aggregates in Nova Scotia by G. Prime.

INDUSTRIAL MINERAL PROPERTIES FOR DEVELOPMENT

In 1988 the Nova Scotia Department of Mines and Energy called for development proposals on three industrial mineral properties including the Chegoggin Point silica deposit, Yarmouth County, the Scotsville barite deposit, Scotsville, Inverness County and the Diogenes Brook silica sand deposit at Melford, Inverness County.

GYPSUM/ANHYDRITE PROJECT[1]

G. Adams

Three goals were established for the Gypsum/Anhydrite Project when it was initiated in 1985 under the Canada-Nova Scotia Mineral Development Agreement. The primary goal was to produce a comprehensive inventory of the gypsum and anhydrite resources of the Province; the second was to increase and enhance relations between the Department and the Province's present producers and the third was to initiate and encourage development of alternate utilization of Nova Scotia's gypsum and anhydrite resources.

Much of the 1987/88 winter was spent preparing promotional materials (including *Information Circular no. 16, Gypsum and Anhydrite in Nova Scotia*) for the 8th Industrial Minerals International Congress held in Boston in April. Preparation of occurrence writeups continued, using information gathered in the field, from assessment reports and reports of Government Core Drills. At winter's end approximately 75% of the occurrences on Cape Breton Island and in Hants County on the mainland had been completed in preliminary form.

During the 1988 field season 136 gypsum and anhydrite specimens were gathered from numerous sites around the Province. Almost all of the Province's gypsum occurrences will have been field checked by autumn 1988 (Fig. 1).

Gypsum quarry production levels have grown steadily from 1980 to 1987. Although no drop in production levels has been noticed in the first two quarters of 1988, most company representatives foresee one by year end because of the general slowing down of the North American construction industry to which the gypsum industry is closely related. The predicted short term decline has in no way discouraged local producers who are in the process of upgrading or renewing facilities, or outlining additional gypsum and anhydrite resources in order to secure their future. Interest in Nova Scotia's gypsum and anhydrite resources for stone production and(or) fabrication of gypsum products remains strong.

Investigations, funded by the Canada - Nova Scotia Mineral Development Agreement, on the use of local anhydrite for a roadside packing system in coal mines, have been completed. Several interested parties await a decision by Devco on a subsurface test in one of their mines in Cape Breton. This test will provide an evaluation of the material in actual working conditions in a mine. A small project, similarly funded, initiated preliminary studies of the production of wallboard from anhydrite. Although moderately successful after limited investigation, this project is currently on hold pending additional funding arrangements.

Although additional detailed work needs to be carried out on specific potential deposit areas, the proposed gypsum/anhydrite inventory is on schedule and should be completed by March, 1989. A good working rapport

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[1] Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

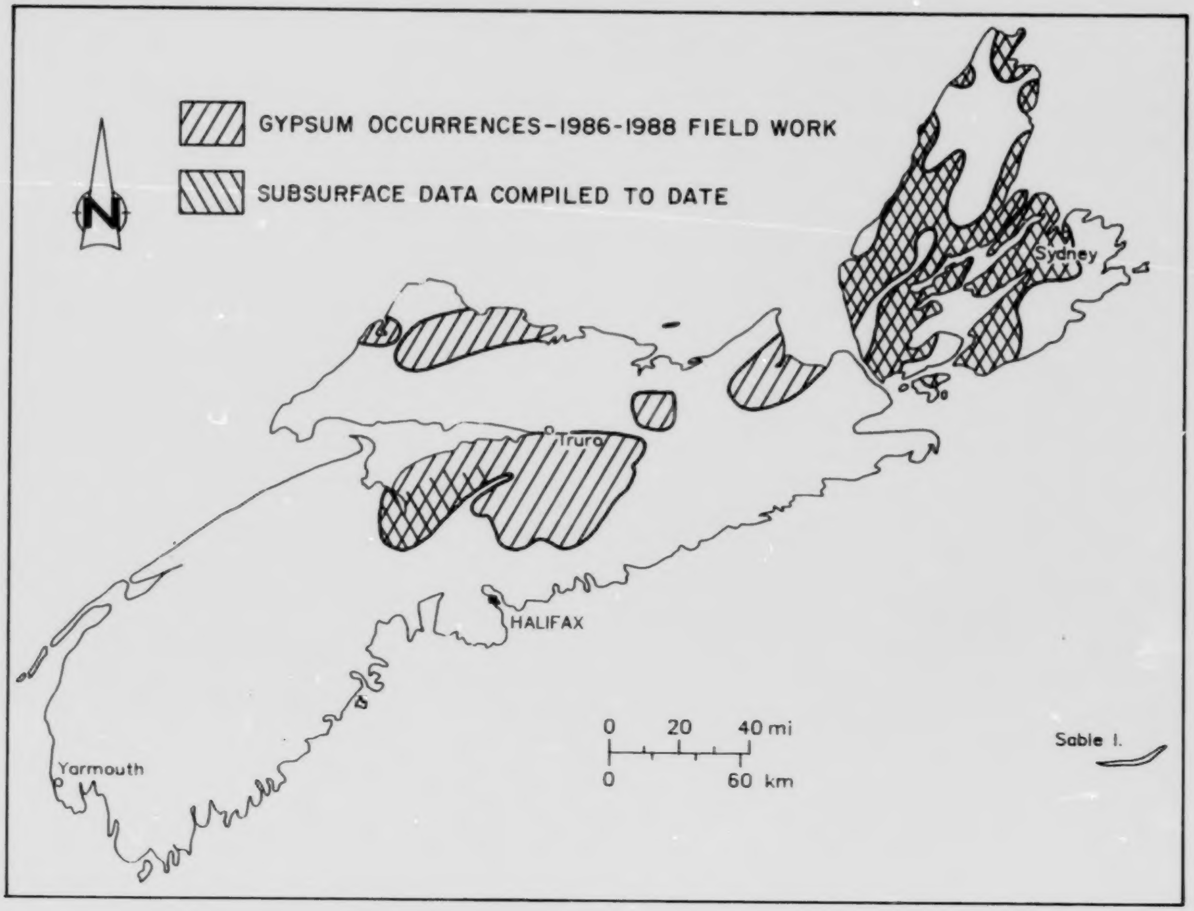
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Figure 1. Gypsum/anhydrite project progress map.

has been established between the Department and the Province's gypsum/anhydrite producers. Alternate resources utilization projects have been successful to date and these initiatives are well received by governments, researchers, producers and potential consumers alike.

AGGREGATE PROJECT[1]

G. Prime

INTRODUCTION

Evaluation of Nova Scotia's aggregate resources continued in 1988. The areas of focus were northern Nova Scotia, where the field investigation phase was completed, and the Halifax - Dartmouth area, where a new study is in progress.

NORTHERN NOVA SCOTIA

The northern Nova Scotia project was initiated to investigate the aggregate potential in Cumberland and Colchester counties. Its implementation was based on serious concerns about the availability of adequate aggregate in some key areas.

A comprehensive field examination of the region has been conducted during the past two years. Evaluation of the aggregate materials found here included an extensive sampling program with over 180 samples collected for analyses. During the course of the program several new aggregate deposits were identified including eskers, kames, alluvial stream deposits, and residuum (weathered bedrock). The final phase of the project, now in progress, is the compilation of data and preparation of a report and maps.

HALIFAX - DARTMOUTH AREA

The Halifax - Dartmouth area has the highest level of aggregate consumption in the Province and is the prime area of concern with respect to future supply. Historically, aggregate demand in the area has been met by using beach materials extracted from nearby deposits. In the 1970s the Beaches Preservation and Protection Act effectively prohibited further removal of these materials throughout the province for environmental reasons. Because there are no land based granular aggregate deposits near the metro area, the industry was forced to look elsewhere to meet the demand. The coarse aggregate materials are obtained from local quarry operations and the sand is transported from distant areas such as Nine Mile River, Coldbrook, and Gays River.

The primary goal of an aggregate producer is to locate an operation as close to the market as possible, thus reducing the high costs associated with transportation. In a densely populated area such as Halifax - Dartmouth, proximity to the market can create conflicts. An example is the ongoing dispute in Waverly where Tidewater Construction has been attempting to open an aggregate quarry for several years but the local residents are opposed. As the metro area population increases, the aggregate industry will continue to encounter these problems.

The objectives of the Halifax-Dartmouth project are to evaluate the aggregate potential in the area and to help avoid conflicts associated with future aggregate development. The emphasis of the study is the identification of bedrock areas surrounding metro where crushed stone aggregate quarries might be developed. Special attention will be directed toward (1) qualitative testing of the aggregate materials, (2) determination of landownership for promising locations and (3) identification of areas of potential conflict.

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[1] Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

The groundwork completed to date for this study includes: (1) a literature search, (2) field checking of some potential areas and (3) preliminary contact with the local aggregate companies. The fieldwork will continue while the weather permits, however, most of the investigation will be conducted in the 1989 field season.

BUILDING STONE PROJECT[1]

G. B. Dickie

INTRODUCTION

Building stone is a term applied to a natural rock that has been quarried and shaped to meet specific requirements for use in the construction, building and monument industries. The term includes such rock types as sandstone, granite and marble. This project was initiated in September 1985 under the Canada - Nova Scotia Mineral Development Agreement to identify and evaluate our building stone resources in response to the increasing demand for information on Nova Scotia building stone deposits and stone products.

Three years of fieldwork have been completed with positive results. Wallace sandstone was used for the first time in many years in the restoration of Province House. The Province House restoration project, completed in late 1987, used 100 m^3 of sandstone and resulted in the successful training of 12 apprentice stone masons over a 2½ year period. The mason apprentices are currently working on restoration of the Dominion Building, which will become the Art Gallery of Nova Scotia. Over 100 m^3 of sandstone from Mary's Point, New Brunswick, is required for this restoration project. In addition, 450 m^3 of Nictaux grey granite and imported black granite are being used for flooring, cladding and a series of planters, resulting in a unique showcase for the international art community. In the coming years many other sandstone buildings will be restored in Nova Scotia and other parts of North America, resulting in a renewed life for Nova Scotia sandstone quarries and continued employment for the newly-trained stone masons.

SANDSTONE DEPOSITS

Work on sandstone deposits was completed during the first phase of this project. Many old quarries were visited and sampled and some were core drilled. Four deposits were selected as the best development opportunities (Fig. 1). The Wallace Quarry, Cumberland County, produces the best-known Nova Scotia sandstone and has been an intermittent building stone producer for over 75 years. Core drilling in late 1986 extended the reserves of olive and grey sandstone to 10 000 m^3 and 32 800 m^3, respectively. The owner stripped a large area of overburden in late 1987 to expose stone for production in 1988.

The Amherst sandstone deposit, although dormant for 50 years, contains an estimated reserve of 27 300 m^3 of excellent quality red sandstone, as indicated by drilling. A deposit of grey sandstone located at Eight Mile Brook, Pictou County, contains a drill-indicated reserve of 25 800 m^3. A new sandstone quarry was opened at Hardwood Hill, Pictou County, in 1987 to supply fill for a local common-user dock project. Diamond-drilling has outlined the presence of tan and olive sandstone which may be suitable for building stone.

GRANITE DEPOSITS

Granite deposits suitable for building

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[1] Funded by the Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

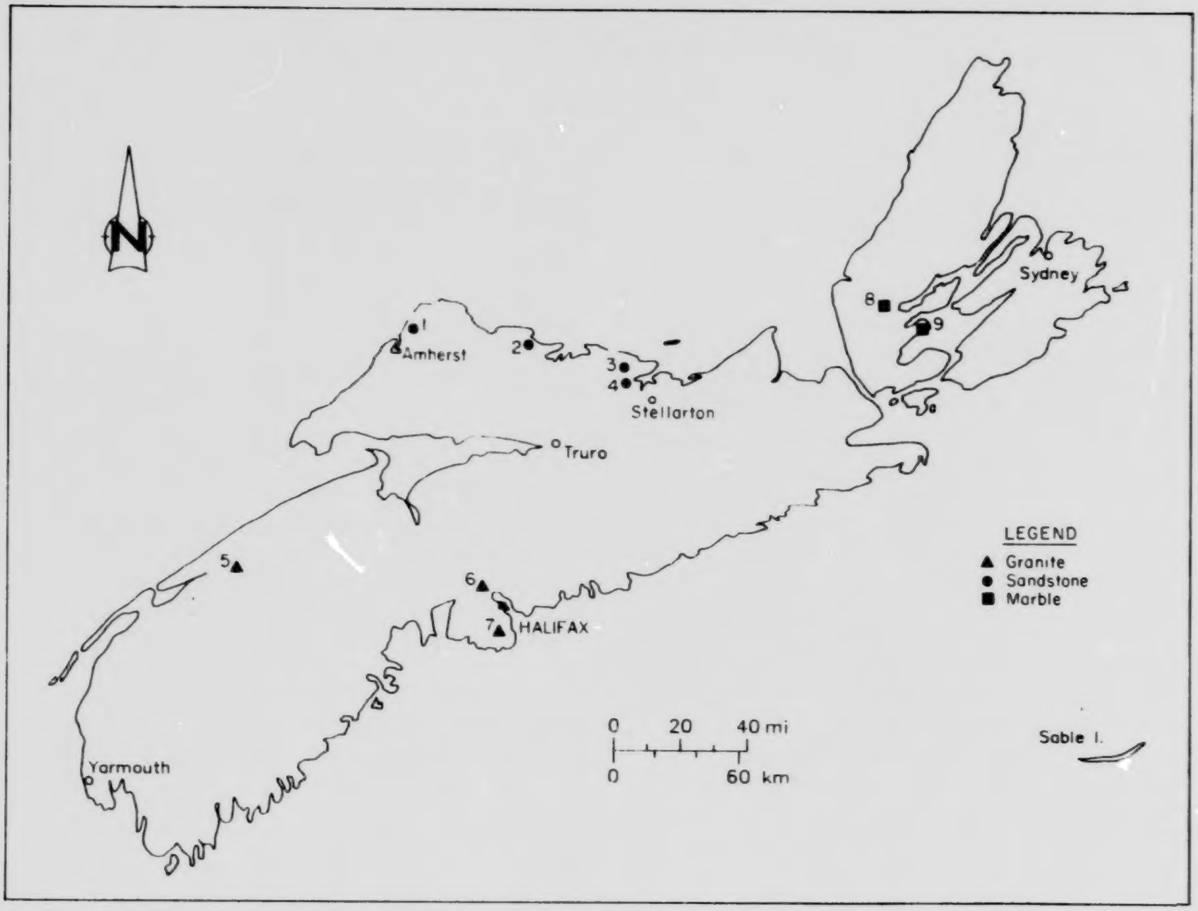

Figure 1. Building stone deposits of Nov Scotia. (1) Amherst Quarry; (2*) Wallace Quarry; (3*) Hardwood Hill; (4) Eight Mile Brook Quarry; (5*) Nictaux Quarry; (6) Quarry Lake; (7) Terence Bay; (8) Glencoe; (9*) Marble Mountain. (*Producer)

stone have been exploited for many years in Nova Scotia. Heritage Memorials Ltd. extract granite from a quarry at Nictaux, Annapolis County, for use as monument blanks and bases. Their annual production is over 500 m^3 of fine grained grey granodiorite.

A white biotite monzogranite was identified at Terence Bay, Halifax County, and diamond-drilled by the Nova Scotia Department of Mines and Energy in 1987. Over 223 000 m^3 of stone were outlined in an area suitable for quarry development.

Grey granodiorite was quarried in several locations in the Halifax area. A site at Quarry Lake has good potential for further development as reserves appear to be large.

A fine- to medium-grained biotite-muscovite granodiorite was quarried in Shelburne on a regular basis until the early 1960s. Although the old 'Island Park' quarry has been filled in, other development opportunities exist in the region.

1988 FIELD PROGRAM

The 1988 field program concentrated on an evaluation of the Glencoe limestone deposit for suitable white and banded marble for use as building stone. Work was carried out mainly on two areas on the east and west sides of the deposit.

Five drillholes totalling 401 m were collared on a white marble on the northeast corner of the Glencoe deposit. A predominantly white to pale blue banded marble was cored for a total thickness of 213 m. Previous drilling indicated that the strike length of the white unit could be 300 m or more. Drilling on the west side of the deposit outlined a band of white marble about 23 m in thickness with a strike extent of over 150 m.

The remainder of the field season will be spent prospecting and mapping the gabbro plugs of Guysborough County and performing a detailed evaluation of granites in the Nictaux area of Annapolis County.

PUBLICATIONS

The *Nova Scotia Building Stone Catalogue* was completed in 1988. It is a promotional catalogue which contains stone sample tiles and descriptive information along with a full colour booklet describing the Nova Scotia industry. Nova Scotia Department of Mines and Energy Information Circular No. 12, *Building Stone in Nova Scotia*, was also completed in 1988. The final report on Nova Scotia building stone resources will be completed in early 1990 and will include all information compiled to date by the Building Stone Project.

VARIOUS COMMODITIES PROJECT[1]

R. H. MacDonald

INTRODUCTION

Nova Scotia possesses several industrial mineral commodities with excellent potential for development. The Various Commodities Project, initiated in May 1986 and funded under the Canada - Nova Scotia Mineral Development Agreement, has attempted to identify and increase the database on deposits with commodities that are presently sought after in the market place.

After an initial period of data compilation and field investigations, commodities with the best potential for development have been investigated in more detail. These commodities include andalusite, barite, celestite, dolomite, fluorite, garnet, graphite, limestone, silica, topaz and wollastonite.

DETAILED INVESTIGATIONS

High grade - large tonnage deposits of limestone and dolomite are in demand and the largest and most promising of these deposits has been investigated in detail. Bulk sampling and diamond-drilling at the limestone/dolomite deposit at Glencoe, Inverness County (Fig. 1), where previous drilling has proven a reserve in excess of 350 million tonnes of cement grade limestone and in excess of 250 million tonnes of metallurgical grade limestone, have been carried out to assess reserves of high quality limestone for use as fillers, extenders and dimension stone.

Bulk sampling, geophysical logging and diamond-drilling have been carried out at the Chegoggin Point, Yarmouth County (Fig. 1), high grade silica and garnet deposit, and reserves in excess of 9 million tonnes of high grade silica and over 500 000 tonnes of biotite schist containing 40-50% garnet have been delineated extending over 3 km inland from the shoreline.

Bulk sampling of the andalusite-muscovite-garnet-magnetite deposit at Doughboy Point, Guysborough County (Fig. 1), has recently been completed and metallurgical testing of this ore is ongoing.

OTHER COMMODITIES INVESTIGATED TO DATE

Numerous limestone/dolomite deposits with potential for development have been field checked, sampled and assayed throughout the Province. Titanium-rich sand deposits along the mouth of the Shubenacadie River have been sampled, assayed, and subjected to metallurgical testing. Talc occurrences throughout the Province have been sampled and assayed.

Commodities that result as a by-product of present mining operations have been collected and assayed. The most promising commodity of this type is the very high grade topaz which is produced as a by-product of the East Kemptville tin operation.

BULK SAMPLE STORAGE SITE

A site prepared adjacent to the Nova

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[1] Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

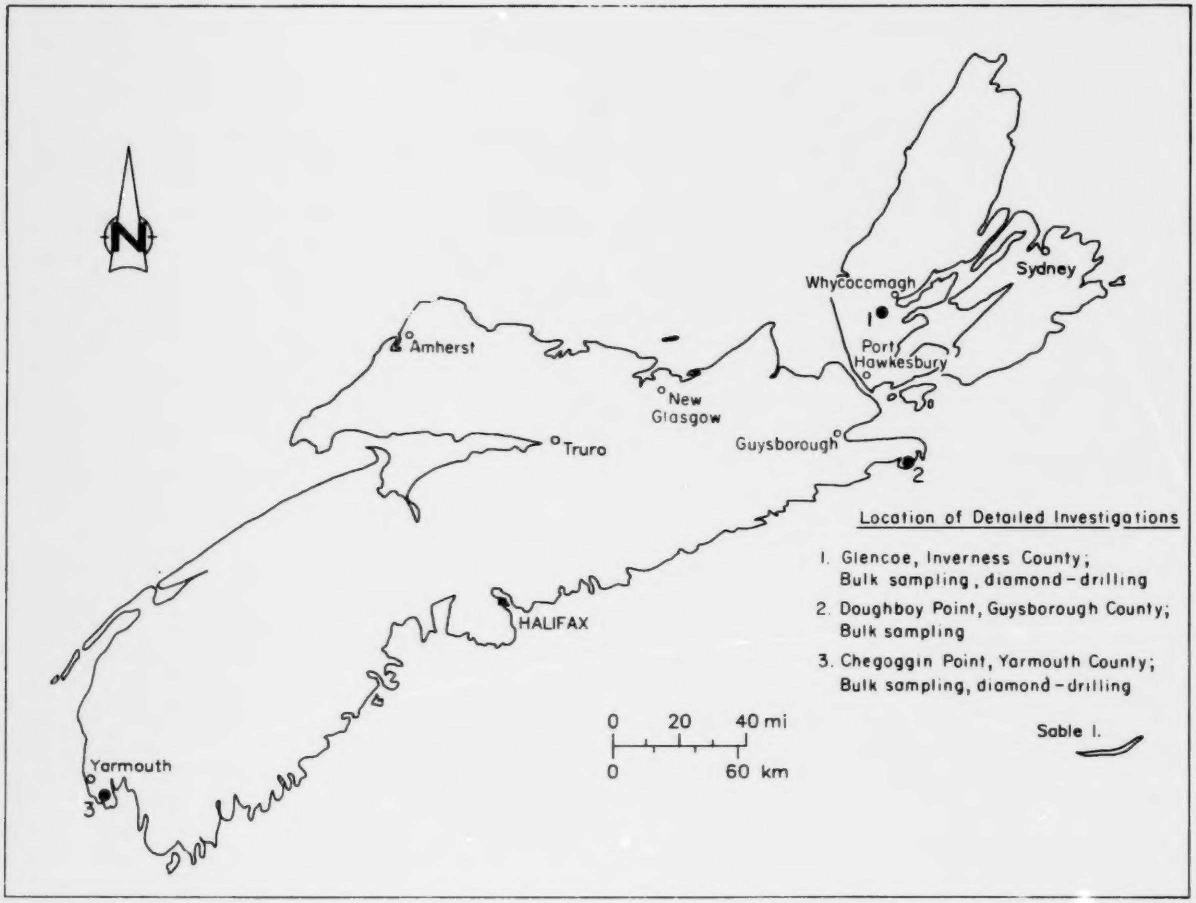
N
Amherst
New Glasgow
Truro
Guysborough
Whycocomagh
Sydney
Port Hawkesbury
HALIFAX
Yarmouth
1
2
3
Location of Detailed Investigations
1. Glencoe, Inverness County; Bulk sampling, diamond-drilling
2. Doughboy Point, Guysborough County; Bulk sampling
3. Chegoggin Point, Yarmouth County; Bulk sampling, diamond-drilling
0 20 40 mi
0 60 km
Sable I.

Figure 1. Map of Nova Scotia showing the locations of three deposits investigated in detail during 1988.

Scotia Department of Mines and Energy core library facility in Stellarton is being used to store bulk samples of the various high interest commodities. These samples can be made readily available year-round to anyone requesting samples for testing. The inventory of available commodities has been expanded this year and samples have been taken from some of these bulk samples for testing. It is hoped that this arrangement will continue to allow better access to samples of the Province's industrial mineral commodities throughout the year.

LAND USE POLICY DEVELOPMENT PROJECT[1]

D. B. Hopper

Through the Canada - Nova Scotia Mineral Development Agreement, the Department is attempting to address the need to promote better understanding of Nova Scotia's mineral and energy resources by industry, the public and other provincial departments. The Land Use Policy Development Project has been developed to channel mineral resource information to the provincial and municipal planning community. The overall objective of this project is to promote proper management and protection of Nova Scotia's mineral resources by providing information, improved communication and resource management guidance to all land use managers.

A three-phased approach has been defined to implement the objectives:

Phase one: Information gathering and creation of a mineral land use information base. Products include 18 county sets of Mineral Resource Land Use (MRLU) maps and handbooks (Fig. 1) covering the Province.

Phase two: Compilation of mineral potential maps of Nova Scotia.

Phase three: Policy recommendations to the Interdepartmental Committee on Land Use concerning mineral, aggregate and energy resource lands. These recommendations form the groundwork for the adoption of a provincial land use policy in accordance with section 7 of the Planning Act.

SURVEY ON MINERAL RESOURCES AND LAND USE

A questionnaire was distributed to Nova Scotia's municipal planners this year to gather information on the interaction between mineral resource activity and land use planning. The questionnaire was divided into four parts which dealt with (1) the current level of land use planning activity in Nova Scotia, (2) types of municipal permit and fee structures required for resource extraction, (3) the perceived availability of mineral resource information by planners and (4) the land use issues planners encounter as a result of mineral based activity or naturally occurring geological hazards.

Preliminary results show that a great deal of land use planning occurs in Nova Scotia. More than 60% of the Province's municipalities have plans and land use by-laws in place. Municipal plan reviews are ongoing in many parts of the Province and over 75% of municipalities with plans have review dates within the next four years. A majority of the respondents to the questionnaire indicated that the Province's initiatives to create detailed inventories of mineral, aggregate and coal resources were very important and useful to the planning process. Similarly, a majority of planners indicated the importance of the Province in providing direction by identifying the mineral, aggregate and coal resources that should be protected

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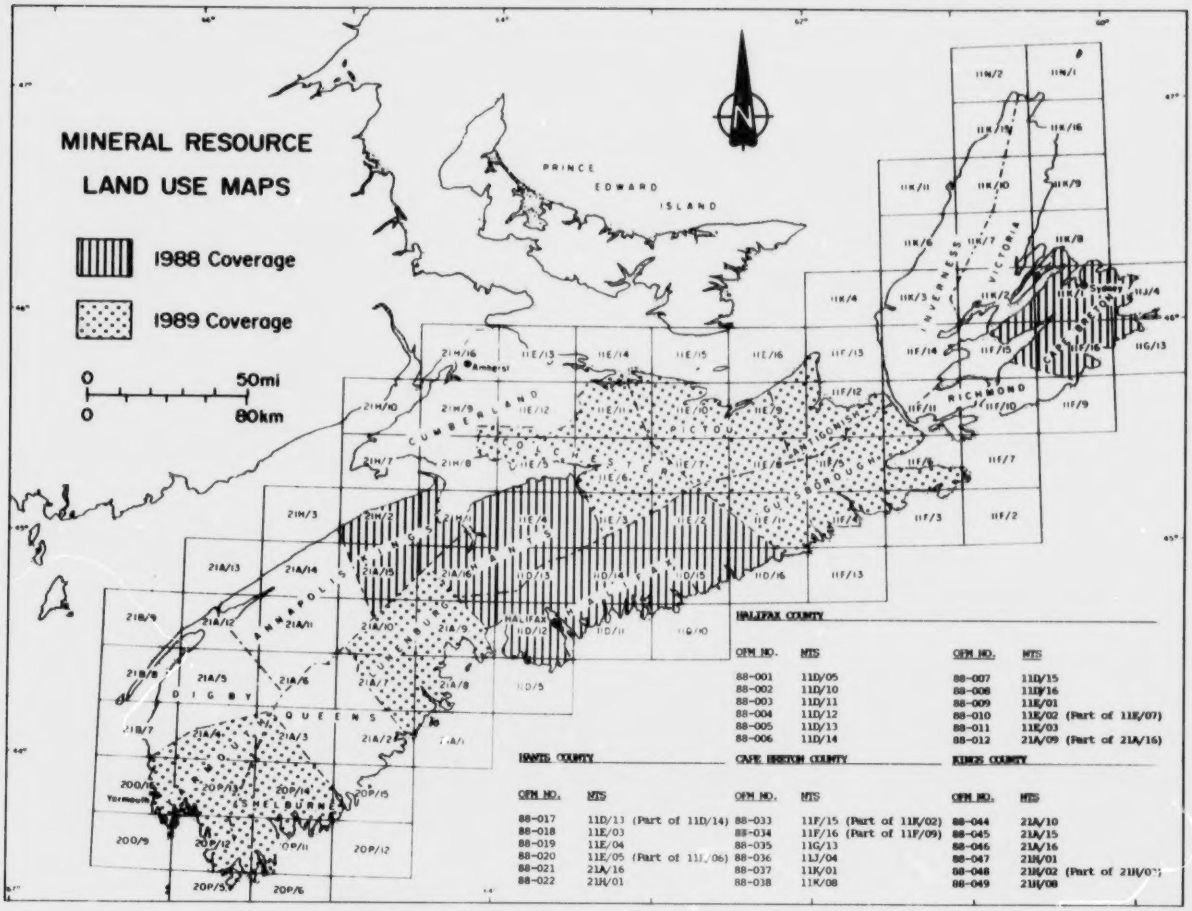
[1] Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement


MINERAL RESOURCE LAND USE MAPS
▥ 1988 Coverage
▨ 1989 Coverage
0 50mi
0 80km
N
PRINCE EDWARD ISLAND
Amherst
Halifax
Yarmouth
Sydney
CUMBERLAND
COLCHESTER
PICTOU
ANTIGONISH
GUYSBOROUGH
HANTS
HALIFAX
KINGS
ANNAPOLIS
LUNENBURG
DIGBY
QUEENS
SHELBURNE
YARMOUTH
INVERNESS
VICTORIA
RICHMOND
CAPE BRETON

HALIFAX COUNTY

OFM NO.	NTS	OFM NO.	NTS
88-001	11D/05	88-007	11D/15
88-002	11D/10	88-008	11D/16
88-003	11D/11	88-009	11E/01
88-004	11D/12	88-010	11E/02 (Part of 11E/07)
88-005	11D/13	88-011	11E/03
88-006	11D/14	88-012	21A/09 (Part of 21A/16)

HANTS COUNTY

OFM NO.	NTS
88-017	11D/13 (Part of 11D/14)
88-018	11E/03
88-019	11E/04
88-020	11E/05 (Part of 11E/06)
88-021	21A/16
88-022	21H/01

CAPE BRETON COUNTY

OFM NO.	NTS
88-033	11F/15 (Part of 11K/02)
88-034	11F/16 (Part of 11F/09)
88-035	11G/13
88-036	11J/04
88-037	11K/01
88-038	11K/08

KINGS COUNTY

OFM NO.	NTS
88-044	21A/10
88-045	21A/15
88-046	21A/16
88-047	21H/01
88-048	21H/02 (Part of 21H/0[illegible]
88-049	21H/08

Figure 1. Mineral Resource Land Use (MRLU) map coverage, 1988 - 1989.

against any potential land use conflict. Respondents to the questionnaire indicated that there is not enough locational information on mineral resources that is suitable for the planning process.

Types of information sought after the most by planners include: environmental effects of resource extraction; locations of mines, quarries and pits; provincial responsibilities over exploration and mining; mineral resource potential; locations of abandoned mine shafts; locations of mineral occurrences; ground subsidence; extent of proven underground resources (especially coal areas); and drillhole locations.

The Land Use Policy Development Project is working to provide Nova Scotia's municipalities with mineral resource land use maps and other materials to provide input to the municipal land use planning process. In so doing we will ensure that multiple and sequential land use planning strategies being developed by municipalities and the Province will incorporate mineral resource information and stress the need for land access by the mineral industry.

MINERAL RESOURCE LAND USE (MRLU) MAPPING

Mineral Resource Land Use maps have been compiled and released for Halifax County (OFMs 88-01 to 88-12), Hants

County (OFMs 88-17 to 88-22) and Cape Breton County (OFMs 88-34 to 88-42). Kings County MRLU maps are in progress and will be available toward the end of the year.

OTHER RESPONSIBILITIES OF THE LAND USE GROUP

AQUACULTURE

Staff of the land use planning project have the responsibility of reviewing applications for aquaculture licenses and experimental permits. This review process allows the Department to screen proposed aquaculture sites for potential conflict with the exploration and mining sector. This is in keeping with the necessity to monitor land and near-shore resource activity in order to maintain a relatively conflict-free land management practice.

MINERAL RESOURCES AND PLANNING

Land Use staff receive many requests for mineral resource information from planners and land managers. In response we have prepared several reports and maps with current information on mineral resources for input to specific land management plans and plan strategies. Staff also provide input to papers and policy produced by the Interdepartmental Committee on Land Use and record and monitor changing land use, such as the designation of ecological reserves and surface water supply watersheds. Staff are also active on Voluntary Planning's Land Resources Coordinating Committee which is largely composed of voluntary representatives from the private sector who have an interest in good land management.

PUBLIC INFORMATION

Members of the Land Use Planning Project combine efforts with the Department's Public Information Program in the production of a Mineral Resource Atlas expected to be released about March 1989.

MINERAL INVENTORY

N. A. Lyttle

BIBLIOGRAPHIC DATABASE ACTIVITIES[1]

(J. Gillespie-Wood, K. Lindgreen, J. Freeman and B. Hawkins)

Indexing and on-line data entry into GEOSCAN continued throughout 1988 for Nova Scotia Department of Mines and Energy (NSDME) bibliographic records. GEOSCAN is a bibliographic database which provides access to publicly available geoscience literature concerning the Canadian landmass and offshore regions. The database presently contains over 121,340 records, and is co-operatively produced from the indexing contributions of 14 federal, provincial and professional geoscience organizations located throughout Canada. The Geological Survey of Canada, through the National GEOSCAN Centre, co-ordinates these indexing activities and provides computer resources in support of this project.

In 1988, 437 new NSDME records were added to GEOSCAN. These records consisted of 134 assessment reports, 41 open file maps, 49 open file reports, 212 publications and 1 journal literature reference, representing a 4.5% increase in the Nova Scotia component of the database. As of August 31, 1988, the database contained 9,859 NSDME records consisting of 4,216 assessment reports, 1,982 publications, 1,266 journal literature references, 961 open file maps, 838 open file reports and 596 theses.

The 5 year bibliographic index *Report 86-4 Index to Publications, Open File Reports, Open File Maps and Theses 1981 to 1985* was released in February 1988, and *Report 87-3 Index to Assessment Reports, Publications, Open File Reports and Open File Maps for 1986* was released in November 1987. Reports in preparation as of August 31, 1988 include *Report 88-2 Index to 1987 Assessment Reports, Publications, Open File Maps and Open File Reports*, an index to Geological Survey of Canada documents on Nova Scotia, and *Report 88-4 Index to Onshore and Offshore Petroleum Exploration Assessment Reports for Nova Scotia*. These indexes are expected to be released in early 1989.

METALLIC MINERAL OCCURRENCES DATABASE ACTIVITIES[2]

(G. Demont)

In an effort to improve the quality and reliability of the data in the Metallic Mineral Occurrences database, a program of systematic reference researching and checking, coupled with selected field checking, was initiated in 1987. The field checking was greatly aided by the efforts of K. Northcote of the NSDME and A. Sangster and W. Ervine of the Geological Survey of Canada. Three hundred and twenty-seven metallic mineral occurrences were researched on map sheets 11E/01, 11E/02, 11E/03, 11E/04, 11E/05, 11E/06, 11E/07, 11E/10, 11E/11, 11E/12, 11E/13, 11E/14, 11F/12, 11K/10, 21A/10, 21H/08, 21H/09, and 21H/16. Two hundred and seventy-six metallic mineral occurrence data cards were revised, 51 occurrences were eliminated, and 24 new metallic mineral occurrence cards were created.

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[1] Funded by Nova Scotia Department of Mines and Energy, and the Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

[2] Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

DRILLHOLES DATABASE ACTIVITIES[2]

(G. Demont)

The Drillholes database contains 17,214 drillhole records consisting of approximately 6 megabytes of data. The database is presently running on Advanced Revelation, and copies of portions of the database (by map sheet), or custom searches, can be obtained on diskette upon request. No additional information was coded and entered into the Drillholes database during 1988 due to a lack of staff to continue this project.

GOLD BIBLIOGRAPHY ACTIVITIES

(J. Gillespie-Wood)

Compilation of information for the gold bibliography, *Report 87-2: Gold in Nova Scotia: a Bibliography of the Geology, and Exploration and Mining Histories from 1832 to 1986*, was completed, and the report was released in November 1987. The bibliography contains more than 1,300 references documenting over 300 gold districts and occurrences. The bibliography is organized into 3 parts: Part I is an alphabetical author index; Part II is an index by gold occurrence, with each gold occurrence subdivided into an author index, an assessment report index, and a map and cross-section index; and Part III contains cross reference lists by gold occurrence, claim reference map, county, status, metallic mineral occurrence card number, and production figures.

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[2] Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Developemnt Agreement

AUTOMATION IN THE MINERAL DEVELOPMENT DIVISION[1]

L. Crust

BACKGROUND

The computing resources of the Mineral Development Division of the Department of Mines and Energy consist of a four-workstation local area network located in the Halifax office and two stand-alone micro-computers located in the Stellarton office.

The local area network in the Halifax office consists of a Compaq Deskpro 286 (with a 130 megabyte hard disk) as a file server, and two Compaq Deskpro 286s (with dual floppy disk drives) and two IBM PC-ATs (each with dual floppy disk drives and 20 megabyte hard disk drives) as workstations. The Stellarton office has an IBM PC-XT and an IBM PC-AT, each of which has dual floppy disk drives and a 20 megabyte hard disk drive.

Most employees of the Halifax office of the Division have some experience using the computers, and with the flexibility offered by the local area network the workstations there are in almost constant use. The micro-computers in Stellarton are heavily used by all Department staff there.

The computers in both offices are being used for database management (using Advanced Revelation and DBASEIII Plus), spreadsheet (using Lotus 1-2-3), communications (using Crosstalk XIV and Crosstalk Mark 4), and word processing (using Word Perfect).

PLANS FOR 1988-89

During the 1988-89 fiscal year the Division plans to upgrade the file server on the local area network and expects to see other divisions place workstations on the network. The Division also plans to purchase workstations for network and database management, the Industrial Minerals group, the Departmental Library in Halifax, and the Core Library in Stellarton.

The Industrial Minerals group is planning to purchase a turnkey system of hardware and software to be used, with the Mining Engineering Division, for the evaluation of mine economics.

The Library has identified a number of manual processes that could be automated, with the creation of a cataloguing/indexing system having the highest priority.

The Word Processing group is planning to purchase the Perfect Pitch software and a communications board, which will allow the Micom 3004 word processor to communicate directly with an IBM PC or compatible workstation on the local area network.

The Drillholes database has been loaded into Advanced Revelation, and the Nova Scotia component of GEOSCAN is also being copied into Advanced Revelation. The development of new databases within the Division is continuing, and the Division will soon be taking advantage of the multi-user and relational capabilities of Advanced

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[1] Funded by the Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

Revelation to build a corporate database on the local area network.

The micro-computer to be purchased for the Core Library will be used for cataloguing the core that is stored there, and will be available for general use by Departmental staff when working in Stellarton.

In the longer term an increased use of electronic communications with our Stellarton office and with other agencies is expected. The divisions of the Mines and Minerals Branch will be developing an integrated system for spatial mapping, analysis and modelling.

FLUID INCLUSION STUDY OF THE BEAVER DAM GOLD DEPOSIT, MEGUMA TERRANE, NOVA SCOTIA[1]

D. J. Kontak, D. MacDonald and P. K. Smith

INTRODUCTION

The presence of fluid inclusions in vein minerals (e.g. quartz, carbonate) associated with ore material provides the only direct evidence regarding the physical and chemical nature of mineralizing fluids. Thus, the study of fluid inclusions forms an integral part of any holistic approach to the examination of ore deposits. The value of such studies is amply demonstrated by Roedder (1984a) where the current state of knowledge on this subject is summarized and implications of fluid inclusion research with respect to igneous and metamorphic petrology, petroleum and sedimentary geology, and ore deposits is presented. With regard to gold mineralization specifically, Roedder (1984b) summarized the results of fluid inclusion studies on 151 gold deposits and noted the following: (1) temperatures of deposition ranged from 100° to 400° with a distinct peak at 200-400° C; (2) the fluids had salinities of <10 wt. % equivalent NaCl; (3) the gold-depositing fluids were frequently rich in CO_2; and (4) evidence of boiling (i.e. effervescence in the case of CO_2-rich fluids) was common in epithermal deposits. The presence of CO_2 is probably important in terms of gold precipitation due to reactions induced by the existence of CO_2 in solution (Kerrich and Fyfe, 1981). More recently the studies of Smith and Kesler (1985), Smith et al. (1984) and Robert and Kelly (1987) on Archean lode gold deposits and the research of Patterson (1986), Steed and Morris (1986) and Goldfarb et al. (1986) on Phanerozoic vein deposits hosted by clastic metasedimentary rocks provide excellent fluid inclusion data for comparison to Meguma gold deposits.

Previous fluid inclusion studies of Meguma Group gold deposits were conducted by Graves (1976) and Yanover (1984). Both researchers recognized the presence of CO_2 and the latter author also detected trace quantities of CH_4.

The current study was designed to see if some characteristic feature of the fluid inclusions (i.e. temperature, chemistry) would be of use in discriminating between auriferous versus barren or low-grade quartz vein systems. The results presented here are preliminary, as research is continuing, but data obtained thus far are discussed in light of their relevance to understanding the origin and constraints on Meguma gold mineralization.

SAMPLING OF VEIN MATERIAL

Detailed underground and surface mapping of the Beaver Dam gold deposit (see Smith and Kontak, 1988) indicates that the quartz vein systems were emplaced into a transient ductile-brittle shear regime such that a simple chronology of vein emplacement is not obvious using either cross-cutting relationships or vein mineralogy. In this study all vein types present in the deposit have been sampled, these

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[1] Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

include: (1) bedding-parallel (BP) veins, (2) discordant or angular veins, (3) fissure veins, (4) pegmatoid veins and (5) cross-cutting or ac veins. Both barren and auriferous veins have been sampled. The degree of deformation of the aforementioned vein types varies dramatically, even for a single vein type, since emplacement of veins relative to the deformation history controls the degree of superimposed strain.

FLUID INCLUSION PETROGRAPHY

Approximately 100 doubly-polished thin sections (average thickness of 90-100 µm) of vein material were prepared and examined. The quality of material varies greatly and depends almost exclusively on the amount of post-crystallization deformation. Where extreme intragranular recrystallization has occurred the quartz is milky white and not amenable to fluid inclusion study. However, in only mildly deformed quartz abundant fluid inclusions of exceptional quality (Fig. 1) are preserved and these correspond to the following types (as observed at room temperature): (1) two phase inclusions of variable shape (i.e. irregular to negative); (2) vapour-rich inclusions where the vapour (V) phase exceeds the liquid (L) phase and may constitute almost 100% of the inclusion; (3) three phase inclusions consisting of LH_2O, LCO_2 and VCO_2 and (4) multiphase inclusions containing one or more solid phases. Type (1) inclusions are by far the most abundant (i.e. >90% of all those seen), whereas type (4) are exceptionally rare. The presence of L- and V-rich inclusions suggests that effervescence occurred, although it is difficult to ascertain how common a phenomenon it was. In addition, all inclusions are considered to be pseudosecondary or secondary in origin, using the rigorous criteria of Bodnar et al. (1985), although the presence of isolated populations of large (20-50 µm) inclusions could be interpreted as representing primary inclusions (Roedder, 1984a). Inclusion types 1, 2 and 3 are illustrated in Figure 1.

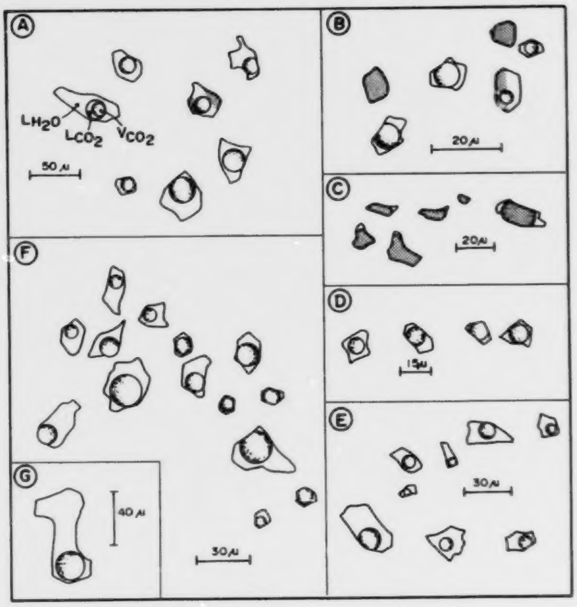

Figure 1. Sketches of typical types of fluid inclusions in quartz sample BD-87-8 from the Beaver Dam deposit. (a) Type 1 inclusions with a single type 3 inclusion. All are CO_2-H_2O types as indicated from freezing experiments. Note the constant L:V ratios. (b) Type 1 and type 2 inclusions coexisting, which indicates that local effervescence occurred. (c) Type 2 inclusions illustrating entrapment of the CO_2 vapour-rich phase during unmixing of a homogeneous H_2O-CO_2 fluid. (d) and (e) Some negative shaped type 1 inclusions with constant L:V ratios. These are the most abundant type of inclusion observed in samples from the Beaver Dam deposit. (f) Isolated group of probable primary inclusions of variable sizes and shapes with constant L:V ratios. (g) Large, irregular shaped, type 1 inclusion of probable primary origin. Summary of heating and freezing data for this sample is presented in Figure 2.

RESULTS OF HEATING AND FREEZING EXPERIMENTS

Heating and freezing data for fluid inclusions were obtained using a USGS Heating-Freezing stage (Roedder, 1984a) purchased from Fluid Inc., Denver, Colorado, and housed at the Department of Mines and Energy. The results obtained for 6 quartz specimens analyzed in detail are presented in Figure 2. We have chosen to study a few representative specimens in detail rather than collect fewer data per specimen from a large number of samples since petrographic studies indicate a remarkable uniformity among the samples. Results are discussed from the lowest to highest temperature phase changes; the important physical changes observed are explained with use of the CO_2 and CO_2-CH_4 phase diagrams in Figure 3.

Upon freezing of inclusions, phase separation of the bubble occurred at about +10 to +25°C indicating the presence of CO_2 and also indicating that almost all of the type 1 inclusions represent a mixed H_2O-CO_2 fluid. Upon further freezing the H_2O and CO_2 phases froze at -40 to -45°C and about -90°C, respectively. Melting of the CO_2 phase varied from -63° to -56°C, indicating 0 - 40 mole % CH_4 dissolved in the CO_2 (Fig. 3).

Melting of clathrates (Collins, 1979) varied from +8° to +12°C; temperatures in excess of +10°C are related to CH_4 impurities (Burruss, 1981) and, therefore, the salinities are probably slightly greater than the 0-4 wt. % equivalent NaCl indicated from clathrate melting temperatures

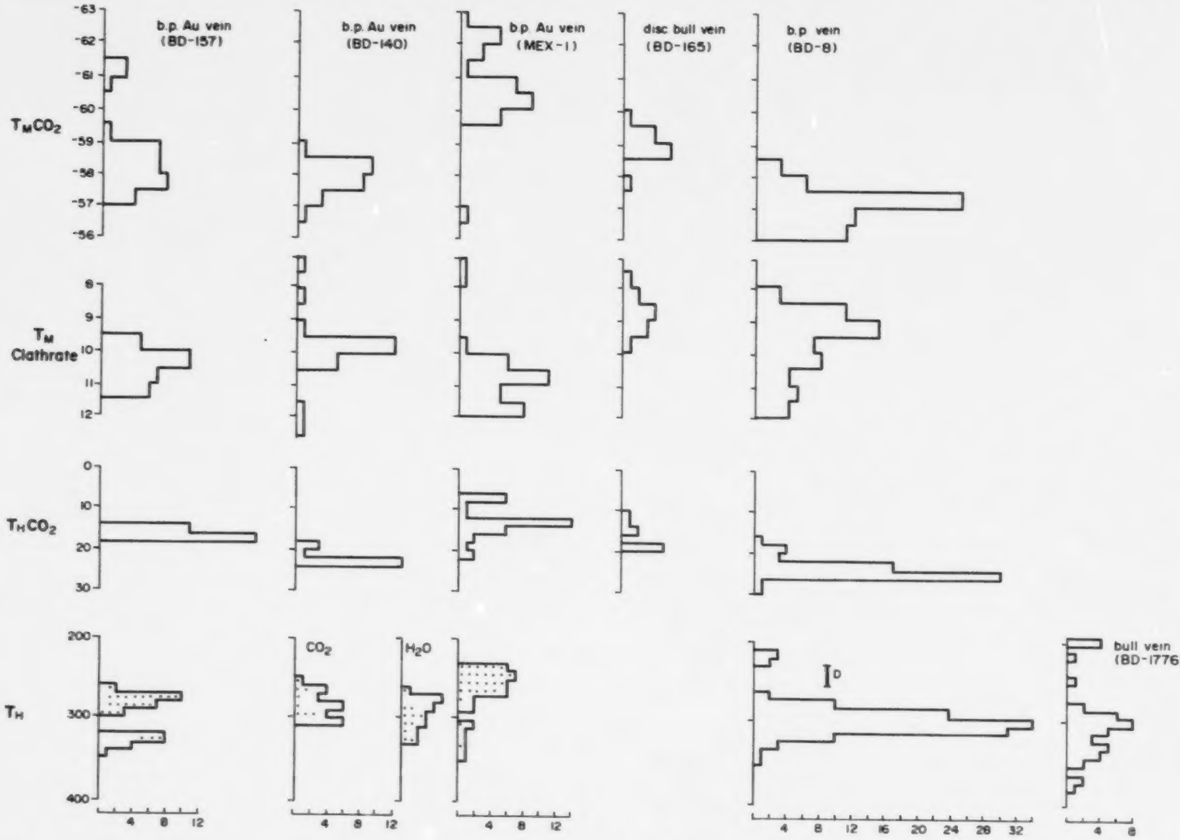

Figure 2. Summary of heating and freezing data for 6 quartz samples from the Beaver Dam deposit. From lowest to highest temperatures the data are for: (1) melting of CO_2 phase, (2) melting of clathrate, (3) homogenization of CO_2 L and V and (4) homogenization of the inclusion to a single homogeneous phase. The single dots represent decrepitation temperatures and b.p. signifies bedding parallel vein.

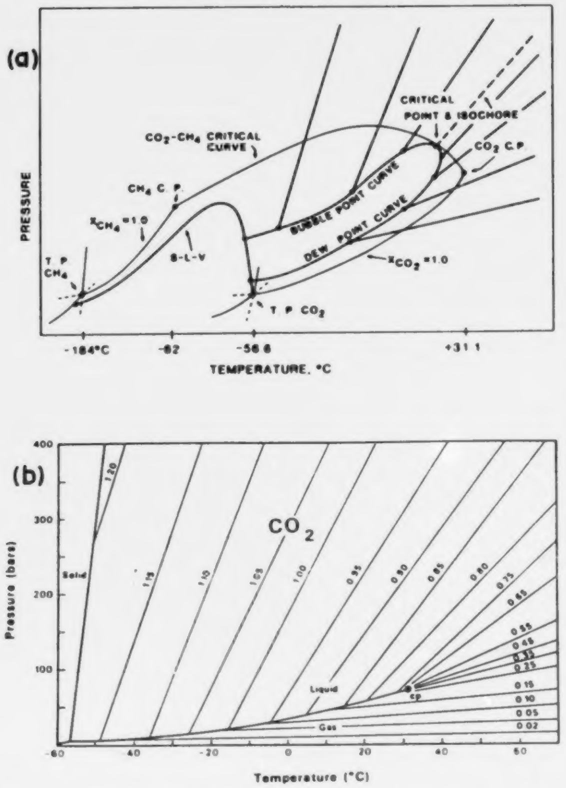

Figure 3. Phase diagrams for the CO_2-CH_4 and CO_2 systems (from Burruss, 1981 and Hollister, 1981, respectively). T.P. and C.P. stand for triple point and critical point, respectively, and the isochores represent lines of constant density (g/cc) in the CO_2 phase diagram.

(Collins, 1979). A few measurements on aqueous inclusions in sample BD-140 gave final melting temperatures of -10° to -4°C (about 7-13 wt. % equivalent NaCl). Homogenization of CO_2 L and V from +8° to +31°C indicates a range in density of 0.87 - 0.60 g/cc for the CO_2 component of the inclusions (Fig. 3).

Homogenization of the inclusions (always to liquid phase) shows a peak at about 300°C, both for the CO_2-H_2O and aqueous types. A large proportion of the inclusions decrepitated prior to homogenization, commonly at or below 300°C. The similar behaviour of the two type 1 inclusions indicate that they probably represent trapping of an immiscible H_2O-CO_2 fluid (Roedder, 1984a).

LEACHATE ANALYSES

Direct chemical analysis of the fluid inclusions can be obtained via leachate analysis, that is by crushing the host mineral and analyzing the released fluid. A modification of the technique used by Robert and Kelly (1987) was used to analyze 14 samples (18 analyses; Fig. 4), again representing a range of variably mineralized vein types. Results indicate that the dominant cations are (in decreasing order) Na, Ca, K, Mg and Fe and that the fluids are remarkably uniform in chemistry despite differences in mineralogy and morphology of the veins. These results are very similar to those of Archean lode gold veins (Robert and Kelly, 1987; Guha et al., 1983), but markedly different from quartz samples from porphyry Cu (Eastoe, 1978) and epithermal Ag-Au (Sawkins et al., 1979; Samson and Banks, 1988) deposits.

DISCUSSION

Results of the present investigation, preliminary as they are, provide some new and important information concerning the nature of the ore-forming fluids at the Beaver Dam deposit, as summarized below.

(1) The dominant inclusion type is a mixed CO_2-H_2O fluid with a composition (mole %) of about 85% H_2O, 13-14% CO_2, 1-2% CH_4 with minor (<4-6 wt. % NaCl equivalent) dissolved salts (Na>Ca>K>Mg>Fe). This fluid composition is similar to that found in other gold deposits (e.g. Robert and Kelly, 1987; Paterson, 1986; Smith et al., 1984).

(2) No difference in inclusion type or composition of fluid is noted for the different vein types, including auriferous versus barren samples.

(3) There is no evidence that gold precipitation can be related to the effervescence or unmixing of a primary, homogeneous CO_2-H_2O fluid phase, a

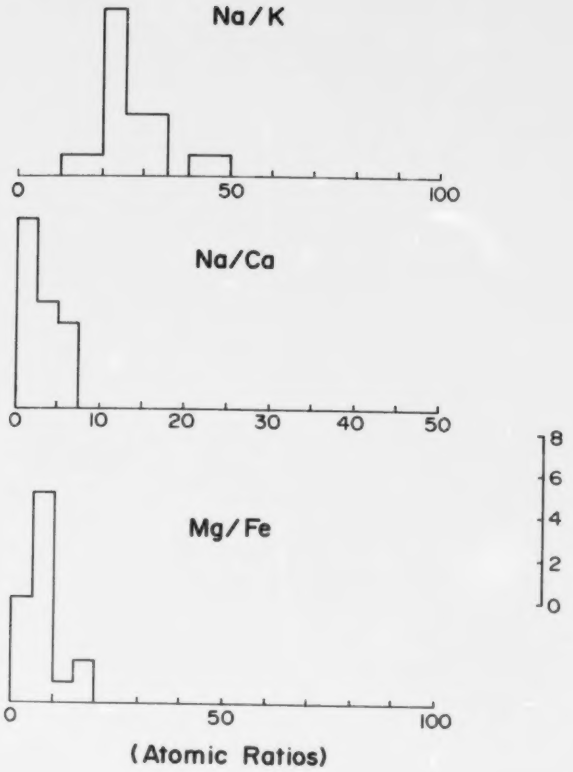

Figure 4. Data for leachate analyses (in ppm) for quartz samples from the Beaver Dam deposit.

mechanism frequently cited as the cause of mineralization in a variety of mineral deposit types (e.g. Robert and Kelly, 1987; Seal et al., 1987). Although effervescence did occur, this phenomenon is present in both barren and auriferous veins and not unique to mineralized zones.

(4) Using the temperature of homogenization and bulk fluid composition the ambient pressure at time of fluid entrapment is estimated to be about 2.5-3.0 kb, using the diagrams of Brown and Lamb (1986), consistent with the 2 kb solvus for low salinity H_2O-CO_2 fluids (Hollister, 1981). Thus, minimum depths of formation are conservatively estimated at about 6-9 km assuming lithostatic pressure (greater depths would be inferred for hydrostatic conditions).

(5) The properties of the inclusions are unlike those derived from magmatic systems (Roedder, 1984a) and, therefore, a dominant component of unmodified, magmatic-derived fluid at Beaver Dam is considered to be improbable.

(6) Preliminary examination of fluid inclusions from other gold districts indicate inclusions are similar with respect to classification and physiochemical properties.

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BISMUTH-TELLURIUM-SILVER-TUNGSTEN ASSOCIATION AT THE BEAVER DAM GOLD DEPOSIT, EASTERN NOVA SCOTIA[1]

P. K. Smith and D. J. Kontak

INTRODUCTION

The Beaver Dam gold deposit is hosted in lower Paleozoic turbidites of the Meguma Group. These strata consist of the basal sandstone-dominated Goldenville Formation which is conformably overlain by the shale-dominated Halifax Formation. The mineralized zones at the Beaver Dam district occur in the Goldenville Formation approximately 4 km below the Halifax/Goldenville contact. The complex structure, metamorphism, igneous intrusion and alteration has been elaborated upon by Smith and Kontak (1988a, b) and Kontak and Smith (1987).

During petrographic and lithogeochemical investigation of the Beaver Dam gold deposit three new, previously unrecognized minerals in Meguma Group gold deposits were encountered.

IDENTIFICATION

The three uncommon mineral phases were identified during reflected light petrographic microscope examination and the results were verified by electron microprobe analysis. Separation of individual minerals for x-ray diffraction study was not attempted because of their small grain size. The new mineral phases recognized are: a bismuth-tellurium-sulphide complex (Bi_4Te_2S), a silver-tellurium alloy ($Ag_{2.5}Te$) and a cadmium sulphide (CdS) (Tables 1 to 4). Bi_4Te_2S and $Ag_{2.5}Te$ are intergrown intimately with galena and larger grains show a zonation with $Ag_{2.5}Te$ forming a core within Bi_4Te_2S. CdS is commonly in grain contact with Bi_4Te_2S and rarely isolated in galena. All galena grains associated with these minerals have highly elevated concentrations (several %) of Bi, Te and Ag in microprobe analysis.

DESCRIPTION

The newly recognized minerals at the Beaver Dam gold deposit occur in quartz veins in the underground workings of the deposit. They are not restricted to any particular portion of the mine nor are they confined to any particular quartz vein type (Smith and Kontak, 1988). They are most prominent in crosscutting, tourmaline bearing, bull and ac type veins. The new minerals have not been recognized in ribbon type veins. Two samples from the mine were selected for microprobe analysis. The samples were taken from a 30 - 50 cm wide gently folded ac type quartz vein on the 1100 m working level and a crosscutting bull type fissure vein from the 1025 m crosscut (Fig. 1). The ac vein mineralogy is characterized by quartz-muscovite-biotite-carbonate-plagioclase-scheelite and minor sulphides and the vein was dated at 370 Ma using conventional $^{40}Ar/^{39}Ar$ stepwise heating methods on fresh vein muscovites (Kontak et al., 1988). The second sample, collected from the bull type vein at the bottom of the mine workings, has vein mineralogy dominated by quartz-tourmaline-plagioclase-

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[1] Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

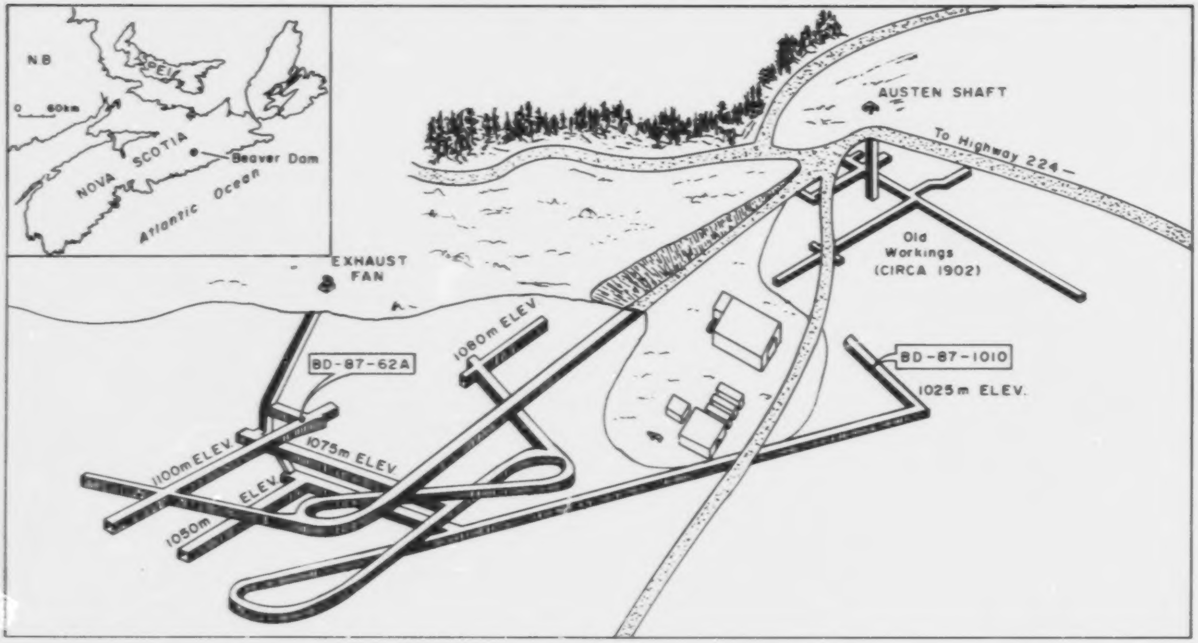

Figure 1. Underground workings of the Beaver Dam gold deposit. Locations of samples BD-87-62A and BD-87-1010 are shown on the 1100 m and 1025 m levels, respectively.

carbonate-chlorite and wall rock fragments as well as minor amounts of sulphides as crosscutting stringers and disseminations. In both samples the gangue minerals show little deformation although the veins do show minor boudinage.

Bi_4Te_2S COMPLEX

Microprobe analyses were conducted on each of the two samples (BD-87-62A [ac vein] and BD-87-1010 [tourmaline bearing bull type fissure vein]) and the results of ten analyses are shown in Table 1. The distribution and character of this mineral complex is shown in Figure 2a-d. Commonly these grains are disseminated throughout larger galena grains or are in contact with galena. The petrographic properties of this mineral are listed below.

colour: light yellow; cream next to pyrite
relative hardness: < galena, < $Ag_{2.5}Te$, < pyrrhotite
polish: good
bireflectance: strong; grey to yellow brown
anisotropism: anisotropic
internal reflections: none
fabric: tabular masses to elongate disseminations

A preliminary identification of the mineral, based on its molecular proportions is Bi_4Te_2S and it is probably a member of the "tellurwismut" series which represents a number of poorly defined mineral species. No specific mineral has been documented for Bi_4Te_2S (Ramdohr, 1980, p. 437-438) and based upon consistent microprobe analyses and petrography, mixed crystal assemblages are not considered. Bi_4Te_2S is intimately intergrown with $Ag_{2.5}Te$. Associated Bi-Te-S minerals include: tetradymite (Bi_2Te_2S), tellurobismutite (Bi_2Te_3), gruenlingite (Bi_4TeS_3), joseite ($Bi_4(Te,S)_3$),

Table 1. Microprobe analyses for bismuth-tellurium-sulphide complex from the Beaver Dam gold deposit (results in %).

SAMPLE NUMBER	BD-87-62A					
PROBE SPOT	56	57	64	65	74	77
Au	0.00	0.00	0.00	0.00	0.00	0.00
Ag	0.13	0.88	0.11	0.14	0.07	0.11
Bi	70.26	70.13	71.01	70.41	71.69	70.15
Te	21.02	20.66	20.85	21.27	20.84	20.96
Fe	0.00	0.01	0.14	0.74	0.00	0.00
Cu	0.00	0.00	0.10	0.06	0.18	0.11
S	2.84	2.68	2.85	2.65	2.71	2.77
TOTAL	94.26	94.37	95.05	95.27	95.49	94.09

SAMPLE NUMBER	BD-87-1010A				AVERAGE
PROBE SPOT	79	80	81	83	N=10
Au	0.00	0.00	0.00	0.00	0.00
Ag	0.81	0.10	0.09	0.11	0.26
Bi	70.48	70.97	71.55	71.26	70.79
Te	21.53	21.80	21.72	21.52	21.22
Fe	0.12	0.09	0.00	0.01	0.11
Cu	0.07	0.02	0.00	0.08	0.06
S	2.75	2.79	2.64	2.80	2.75
TOTAL	95.76	95.76	95.99	95.78	95.18

pilsenite (Bi_3Te_2) and oruetite (Bi_8TeS_4).

Ramdohr (1980) suggests that these minerals are common in hypothermal and mesothermal auriferous quartz vein type deposits and, in thermal contact areas, are often associated with native gold.

$Ag_{2.5}Te$ ALLOY

In association with the bismuth-tellurium-sulphide complex is a silver-tellurium alloy ($Ag_{2.5}Te$). Two representative microprobe analyses are shown in Table 2 and the alloy's petrographic habit is indicated in Figure 2b-d. The petrographic properties of this mineral are listed below.

colour: olive grey brown
relative hardness: < greenockite, Bi_4Te_2S
polish: good, minor pitting on surface
bireflectance: strong, dark grey to brown
anisotropism: anisotropic
internal reflections: none
fabric: irregular to elliptical masses

Although the mineral composition

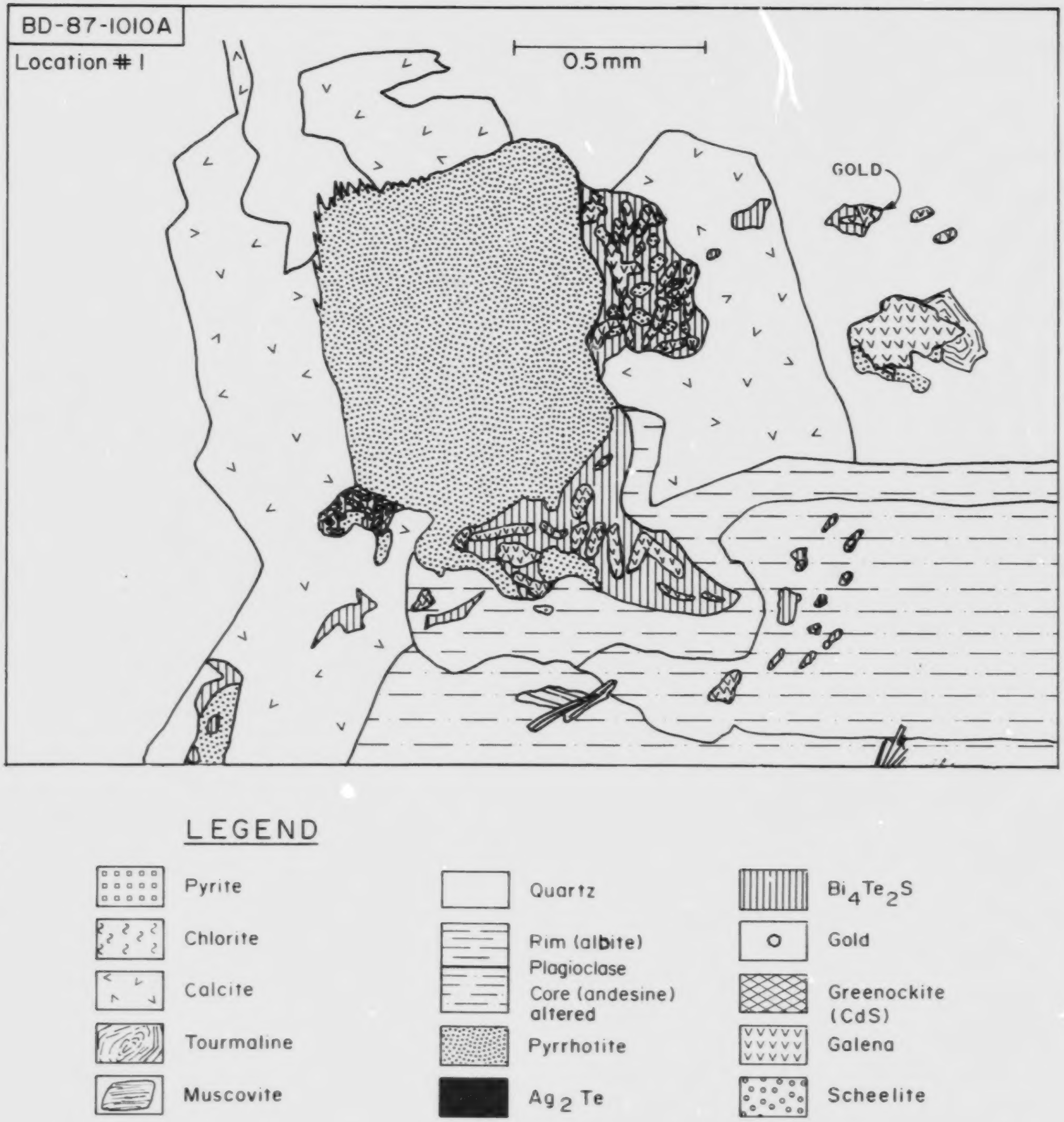
BD-87-1010A
Location # 1
0.5 mm
GOLD
LEGEND
Pyrite
Chlorite
Calcite
Tourmaline
Muscovite
Quartz
Rim (albite)
Plagioclase
Core (andesine) altered
Pyrrhotite
Ag2 Te
Bi4Te2S
Gold
Greenockite (CdS)
Galena
Scheelite

Figure 2a. Sketch of polished thin section (BD-87-1010A) showing the association of Bi_4Te_2S with gold, pyrrhotite and galena in a tourmaline-rich quartz vein. Associated gangue minerals include saussuritized plagioclase, muscovite, tourmaline and calcite surrounded by quartz.

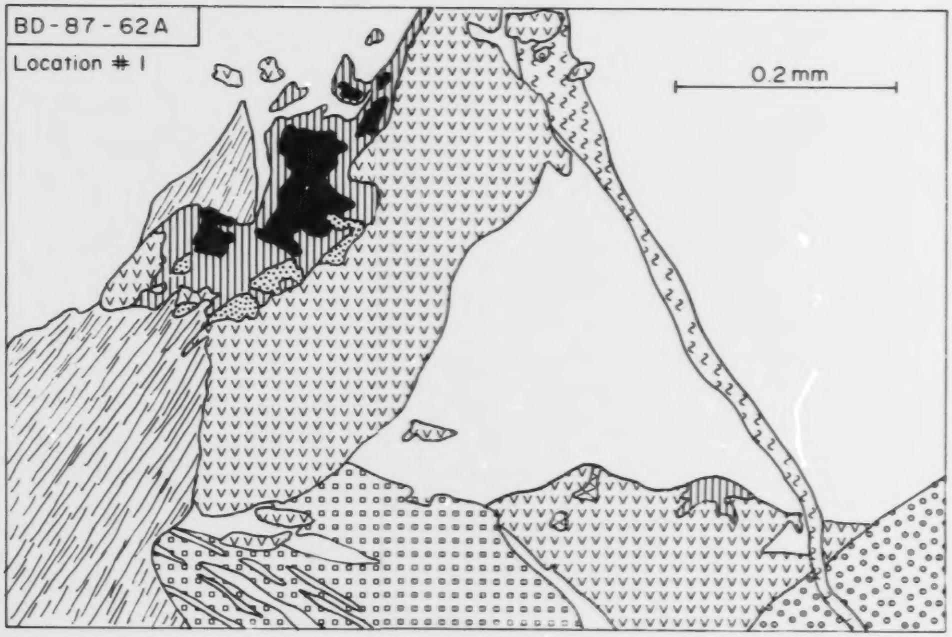

Figure 2c. Sketch of polished thin section (BD-87-62A) showing the distribution of Bi_4Te_2S, $Ag_{2.5}Te$ and CdS minerals in ac type quartz vein. Associated vein minerals include pyrrhotite and galena in a quartz host. Sketch is of microprobe location #2.

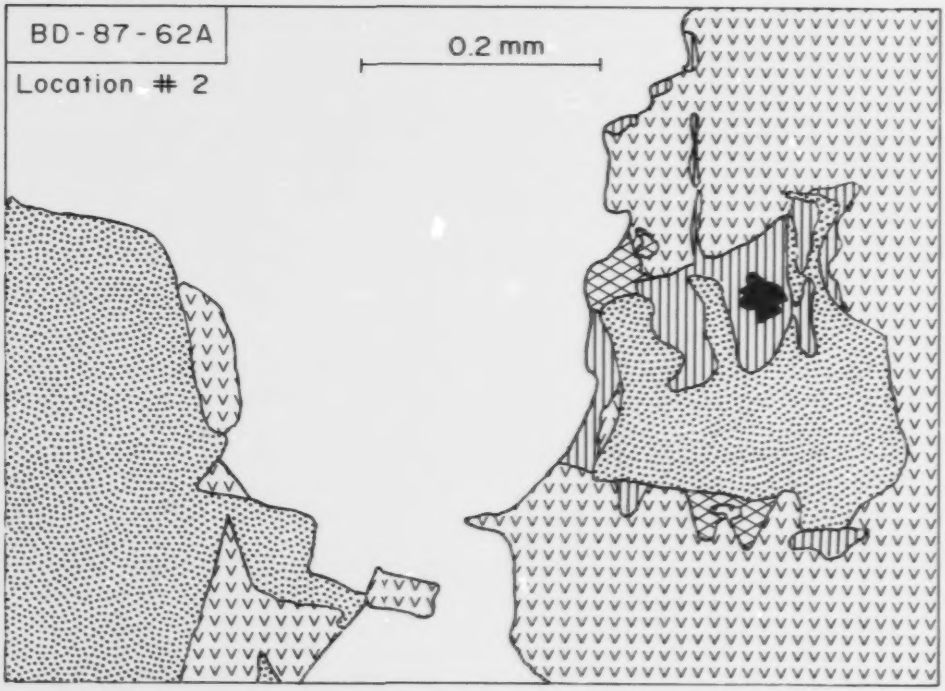

Figure 2b. Sketch of polished thin section (BD-87-62A) showing the distribution of Bi_4Te_2S and $Ag_{2.5}Te$ at microprobe location #1. Galena and pyrrhotite are the dominant associated ore minerals. Minor greenockite (CdS) is present in contact with galena. Scheelite is common in this ac type vein but there is no spatial association of scheelite and Bi_4Te_2S, $Ag_{2.5}Te$ and CdS.

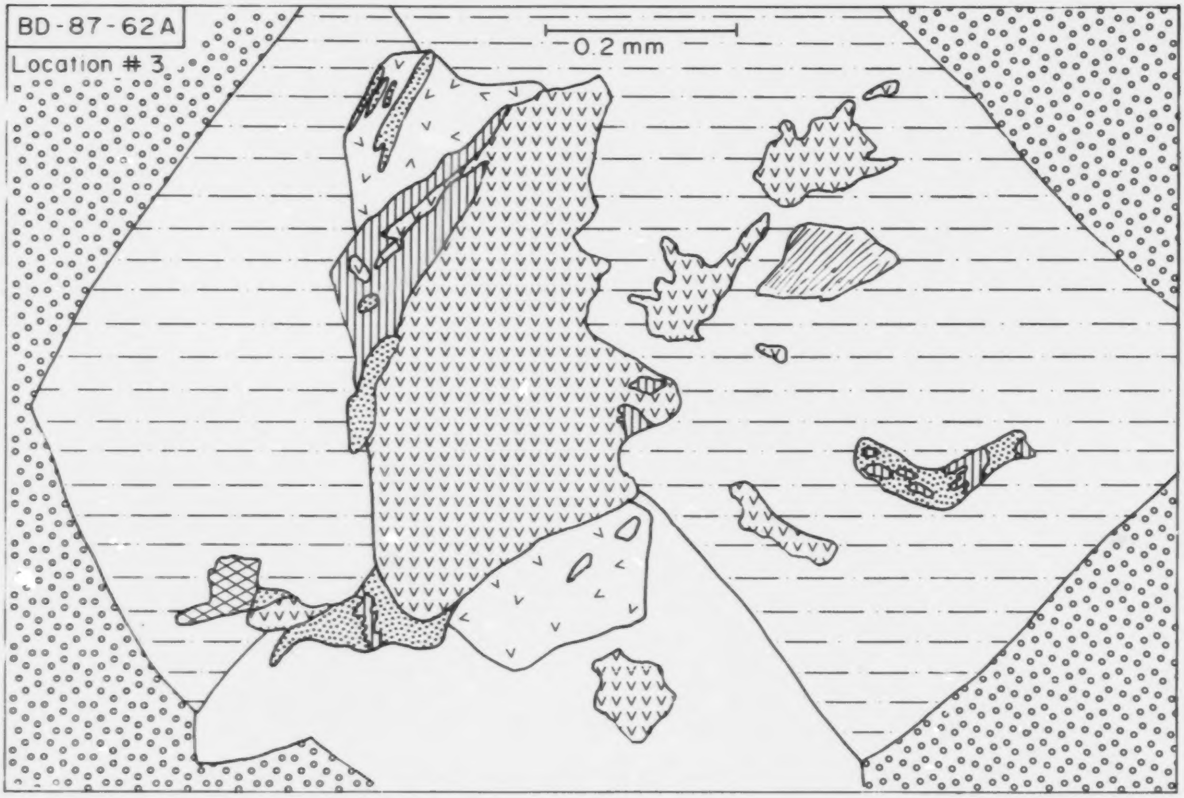

Figure 2d. Sketch of polished thin section (BD-87-62A), microprobe location #3, showing the distribution of associated mineralogy in a scheelite cavity. The dominant host mineral in the cavity is strongly saussuritized plagioclase with late stage quartz and calcite. Galena and pyrrhotite are the main minerals assoicated with Bi_4Te_2S, $Ag_{2.5}Te$ and CdS phases.

(based on microprobe analysis) is intermediate between "hessite" and "stutzite", the optical properties of this mineral are slightly varied. This mineral species is less common at Beaver Dam than the bismuth complex but the two phases are intimately associated. Common minerals which are assumed to be related to this alloy/mineral include: stutzite (Ag_5Te_3), hessite (Ag_2Te) and empressite (AgTe).

Ramdohr (1980, p. 425) notes a transition from empressite to stutzite according to the following reaction:

$$AgTe\ \underline{\geq 210^\circ C}\ Ag_5Te_3 + Te_2$$

Further investigation of this mineral phase is required to check its chemical and physical properties and verify its identification.

GREENOCKITE (CdS)

Greenockite (CdS) occurs in one sample (BD-87-62A), intimately associated with the two mineral phases described above. Microprobe analyses are listed in Table 3 and the mineral habit is shown in Figures 2b-d. The petrographic properties of this mineral are listed below.

colour: dark grey
relative hardness: > $Ag_{2.5}Te$

Table 2. Microprobe analysis of $Ag_{2.5}Te$ alloy from the Beaver Dam gold deposit (results in %).

SAMPLE NUMBER	BD-87-62A		AVERAGE
PROBE SPOT	75	76	N=2
Au	0.00	0.00	0.00
Ag	62.73	64.31	63.52
Bi	0.00	0.00	0.00
Te	35.25	36.13	35.69
Fe	0.00	0.00	0.00
Cu	0.00	0.00	0.00
S	0.10	0.14	0.12
TOTAL	98.08	100.58	99.33

polish: good
bireflectance: internal reflections too strong to observe
anisotropism: internal reflections too strong to observe
internal reflections: bright reddish brown
fabric: elongate masses

CdS is a component of all sphalerites and is common in zinc deposits around the world (e.g. Bolivia). Although sphalerite occurs at all gold districts in the Meguma Group, it was not noted in any of the samples containing greenockite. It is however, intimately intergrown in some galena grains. This sample from Beaver Dam is the only one containing greenockite that has been identified in the Meguma Group gold deposits to date. The mineral is generally indicative of low temperature hydrothermal deposits (Ramdohr, 1980).

The three minerals described above have a close temporal and spatial association with galena, scheelite and gold in the samples that were examined.

LITHOGEOCHEMISTRY

Trace element analyses for Ag, Au, Bi, Pb and W are reported for 28 selected whole rock samples containing elevated levels of one or more of these elements (Table 4). The average of all elements is well above background values for the Meguma Group (Smith, 1984). All of those samples with anomalous values of bismuth contained visible grains of Bi_4Te_2S and $Ag_{2.5}Te$. Log-log plots of bismuth versus lead (Fig. 3a), silver versus bismuth (Fig. 3b) and silver versus lead (Fig. 3c) show linear correlation. However, a plot of silver versus gold (Fig. 3d) shows a random distribution pattern. Tungsten does not correlate well with any of the above elements although it is geochemically anomalous in many of the samples containing the three newly identified minerals.

CONCLUSIONS

Newly identified minerals at the Beaver Dam gold deposit occur in auriferous quartz veins dated at 370 Ma. They have a close temporal and spatial association with galena, scheelite and gold although no tellurium- or bismuth-bearing gold minerals have been observed. Similarities between Beaver Dam and the rest of the gold districts in southeastern Nova Scotia dictate that similar exotic mineralogy may be present at other deposits.

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Table 3. Microprobe analysis of CdS (greenockite) from the Beaver Dam gold deposit (results in %).

SAMPLE NUMBER	BD-87-62A				AVERAGE
PROBE SPOT	66-1	66-2	66-3	66-4	N=4
Au	0.00	0.00	0.00	0.00	0.00
Ag	0.12	0.14	0.00	0.12	0.10
Bi	0.00	0.00	0.00	0.00	0.00
Te	0.00	0.00	0.00	0.00	0.00
Fe	2.30	2.12	2.14	1.73	2.07
Cu	0.00	0.00	0.00	0.00	0.00
S	22.70	22.51	22.69	22.84	22.69
Cd	72.29	74.52	74.54	74.52	73.97
TOTAL	97.41	99.29	99.37	99.21	98.82

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Table 4. Partial whole-rock trace element chemistry for selected samples representing the various quartz vein types for the Beaver Dam gold deposit. Only samples anomalous in one or more of the elements shown have been selected for this table.

SAMPLE ELEMENT	BD-87-18 RIBBON	BD-87-27 TOURM	BD-87-28 TOURM	BD-87-35 BULL	BD-87-43A BULL
Ag (ppm)	26.00	0.80	0.90	1.10	0.10
Au (ppb)	10.00	10.00	10.00	10.00	488.00
Bi (ppm)	88.00	1.90	0.44	0.12	0.09
Pb (ppm)	6600.00	79.00	106.00	188.00	17.00
W (ppm)	7.00	7.00	19.00	70.00	15.00

	BD-87-44 EN-ECH	BD-87-45 BULL	BD-87-46 BULL	BD-87-47 BULL	BD-87-51A TOURM	BD-87-53 BULL
Ag	0.30	0.20	0.80	0.60	0.20	0.50
Au	88.00	10.00	30.00	10.00	120.00	725.00
Bi	0.09	0.11	1.80	6.00	0.07	45.00
Pb	23.00	18.00	92.00	108.00	15.00	44.00
W	19.00	19300.00	10.00	15.00	9300.00	1140.00

	BD-87-56 BULL W/ARG	BD-87-57 BULL	BD-87-58 BULL	BD-87-60 STRATAB	BD-87-61 AMPH V.	BD-87-62 AC
Ag	1.20	0.80	0.30	0.90	0.30	117.00
Au	10.00	1625.00	10.00	10.00	10.00	60.00
Bi	2.50	2.30	0.09	0.23	0.12	470.00
Pb	82.00	42.00	14.00	222.00	94.00	7300.00
W	28500.00	44500.00	27100.00	10.00	1740.00	25640.00

Table 4. (cont'd)

	BD-87-69 SIDE	BD-87-75 BULL	BD-87-76 BULL	BD-87-87 TOURM	BD-87-98 EN-ECH	BD-87-1004 TOURM
Ag	4.70	0.90	0.20	1.60	6.00	0.40
Au	23.00	788.00	10.00	105.00	775.00	10.00
Bi	17.00	1.70	0.12	1.00	12.00	0.75
Pb	1200.00	41.00	100.00	70.00	750.00	24.00
W	17.00	1582.00	7.00	2.00	2.00	3.00

	BD-87-100 EN-ECH	BD-87-1006 TOURM	BD-87-1008 BULL	BD-87-1009 TOURM	BD-87-1010 TOURM	AVERAGE N=28
Ag	12.50	0.10	0.20	5.70	0.70	6.60
Au	187500.00	18.00	1750.00	1125.00	70.00	6978.93
Bi	0.05	0.07	62.00	57.00	1.50	27.57
Pb	4.00	4.00	33.00	86.00	58.00	621.93
W	2.00	50.00	6.00	7.00	10.00	5681.43

KEY

RIBBON	RIBBON TYPE QUARTZ VEIN
TOURM	TOURMALINE BEARING QUARTZ VEIN
BULL	BULL TYPE CROSSCUTTING QUARTZ VEIN
EN-ECH	EN-ENCHELON OR IRREGULAR QUARTZ VEIN
W/ARG	WITH A MINOR AMOUNT OF ARGILLITE
STRATAB	STRATABOUND QUARTZ VEIN
AMPH V.	AMPHIBOLE RICH PORTION OF A STRATABOUND BEIN
AC	AC TYPE QUARTZ VEIN
SIDE	IRREGULAR QUARTZ VEIN ON THE SIDE OF ANOTHER VEIN

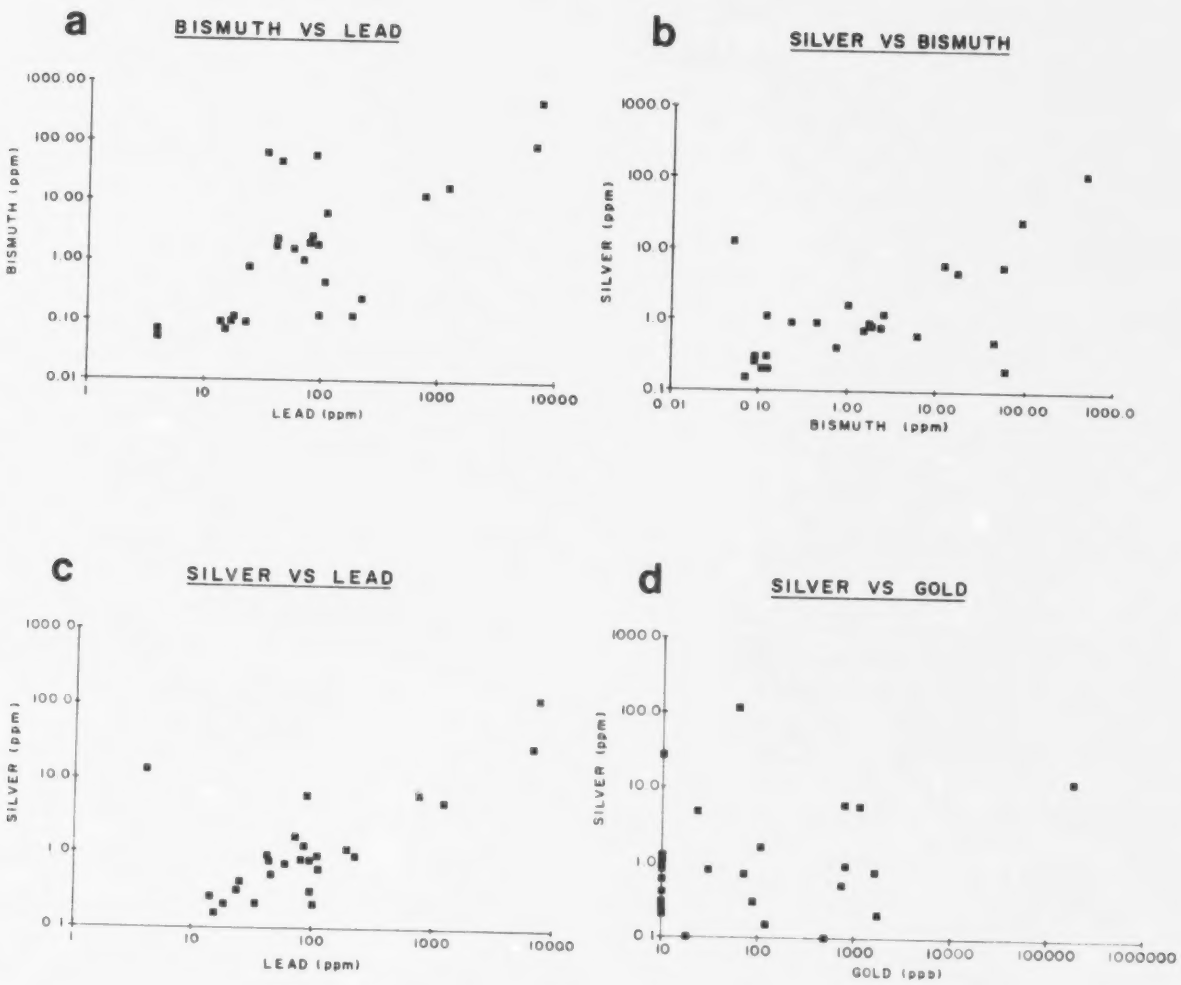

Figure 3. Log-log plots of (a) bismuth vs. lead, (b) silver vs. bismuth, (c) silver vs. lead and (d) silver vs. gold for selected quartz veins from the Beaver Dam gold deposit.

EAST KEMPTVILLE PROJECT: WHOLE-ROCK AND MINERAL CHEMISTRY, STABLE ISOTOPES AND FLUID INCLUSION STUDIES - A PROGRESS REPORT[1]

D. J. Kontak

INTRODUCTION

Petrological, isotopic and fluid inclusion studies of the host granite and mineralized greisens and veins at the East Kemptville tin, base metal and precious metal deposit, located in Yarmouth County, southwestern Nova Scotia, provide additional information directed toward a comprehensive study of this mineralized centre. The initial field investigations (Kontak et al., 1986) and subsequent field and laboratory studies (Kontak, 1987a, b, c; Kontak et al., 1988a) indicate that the East Kemptville deposit is hosted by a specialized topaz granite, petrologically distinct from the more prominent and intensely studied South Mountain Batholith (SMB; Clarke and Muecke, 1985 and references therein), which was generated and emplaced in an active ductile shear zone. The age of 300 Ma suggested by Zentilli and Reynolds (1985) has been questioned (Kontak, 1987a), as has the hydraulic fracturing model of Richardson et al. (1982) (Kontak, 1987c). This report summarizes and discusses new data pertaining to the genesis of the East Kemptville leucogranite and associated mineralization. Results are still incomplete, thus, subsequent modification of conclusions is probable.

ANALYTICAL SOURCES

Whole-rock chemical analyses were obtained at Technical University of Nova Scotia (major elements), Bondar-Clegg, Ottawa (trace elements), Carleton University, Ottawa (Rare Earth Elements (REE)), and St. Mary's University, Halifax (REE). Mineral chemistry was obtained at Dalhousie University, Halifax, for major elements (electron microprobe) and Memorial University of Newfoundland, St. John's, for trace elements (ICP-MS). Stable isotopic analyses for oxygen were performed at University of Saskatchewan, Saskatoon, and for sulphur at McMaster University, Hamilton. Fluid inclusion data were acquired using a United States Geological Survey - designed heating-freezing stage modified and distributed by Fluid Inc., Denver, Colorado; the equipment is maintained at the Department of Mines and Energy.

WHOLE-ROCK AND MINERAL CHEMISTRY OF EAST KEMPTVILLE LEUCOGRANITE (EKL)

Results of initial petrological studies of the EKL were reported by Kontak (1987a). In this work the specialized nature of the granite was discussed and a comparison with the topaz granites/rhyolites and ongonite suites was made. Continued petrological studies of the EKL now include analyses of the whole rocks for oxygen isotopes, REE analyses and chemical analyses of the major mineral phases. A detailed discussion of the petrology of the EKL is in preparation and will be reported elsewhere.

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OXYGEN ISOTOPE DATA

Whole-rock oxygen isotope data have been obtained for 5 samples of EKL, including 4 medium grained phases and a single fine grained dyke rock. $\delta^{18}O$ values for the 4 granites range from 8.6 to 10.3°/.. (x=9.1 ± 0.7°/..) with a considerably more elevated value of 12.2°/.. for the dyke rock sample. These values contrast with an average $\delta^{18}O$ of 10.7 ± 0.7°/.. for all granitoid phases of the SMB (n=54; Kontak et al., 1988b). Although additional data are required to confirm this apparent difference, this information is consistent with other chemical and mineralogical indicators which collectively suggest different petrogenetic origins for the SMB and EKL.

RARE EARTH ELEMENT DATA

REE data have been acquired for 12 whole rocks of the EKL and the chondrite-normalized profiles for 6 of these (analyses from Carleton University) are summarized in Figure 1 where they are compared with other specialized felsic suites and with evolved members of the SMB. The REE data are characterized by their low overall abundances (i.e. <10 times chondritic values), unfractionated patterns and distinct concave-up shapes to the HREE profiles. This latter feature probably reflects the effects of fluorine complexing in the melt (e.g. Strong et al., 1984), while the unfractionated LREE pattern is consistent with extensive monazite fractionation (e.g. Montel, 1986). The patterns contrast markedly with evolved members of the SMB and typical patterns for topaz granites (Taylor et al., 1985) and topaz rhyolites (Christiansen et al., 1986). The EKL patterns are instead more similar to the REE profile for the volatile- and metal-rich Macusani glass of southeast Peru (Pichavant et al., 1987; Fig. 1), although the latter is more depleted in the HREE.

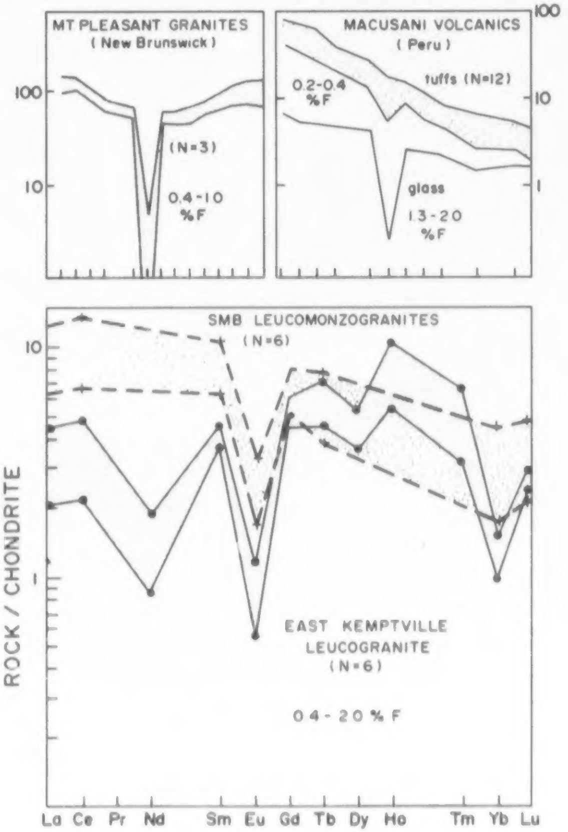


Figure 1. Chondrite-normalized REE profiles for the East Kemptville leucogranite compared to data from leucomonzogranites of the SMB (Muecke and Clarke, 1981), Mt. Pleasant topaz granite, New Brunswick (Taylor et al., 1985), and Macusani volcanics (Pichavant et al., 1987). Data for the EKL are those obtained from Carleton University (R. P. Taylor, personal communication, 1987) and are similar to additional analyses obtained at St. Mary's University (J. Dostal, personal communication, 1987).

MINERAL CHEMISTRY

Representative electron microprobe analyses of the major mineral phases of the EKL are presented in Table 1 and the important results are summarized below.

Table 1. Representative mineral analyses for the East Kemptville leucogranite.

	1	2	3	4	5	6	7	8	9	10	11
SiO_2	39.12	41.33	44.94	28.29	43.68	48.82	47.08	-	33.00	63.49	68.62
TiO_2	1.14	0.94	0.39	0.12	0.10	0.20	0.24	-	-	-	-
Al_2O_3	18.70	21.54	20.06	17.21	31.97	28.87	24.60	-	56.54	18.61	19.05
Cr_2O_3	0.11	0.12	0.09	0.11	0.09	-	-	-	-	-	-
FeO	24.99	19.19	15.54	37.68	9.07	6.48	9.42	-	0.11	0.18	0.16
MnO	0.40	0.19	0.35	1.08	0.33	0.30	0.09	1.67	-	0.07	0.20
MgO	0.39	0.66	0.37	0.18	0.21	0.26	0.26	-	-	-	-
CaO	0.13	0.09	0.10	0.32	0.28	0.01	0.03	53.94	-	0.10	0.00
Na_2O	0.15	0.18	0.11	0.17	0.11	0.17	0.16	0.00	-	0.43	11.45
K_2O	9.54	10.02	10.04	0.11	0.25	10.40	10.85	-	-	16.41	0.09
F	2.21	3.26	3.19	0.06	0.41	2.01	2.90	3.45	16.08	-	-
P_2O_5	-	-	-	-	-	-	-	42.20	-	-	-
	96.86	98.20	95.18	85.34	86.49	97.52	95.57	101.25	105.73	99.29	99.55
$F \equiv O$	0.92	1.36	1.33	0.02	0.17	0.84	1.21	1.44	6.76	-	-
Σ	95.94	96.84	93.75	85.32	86.32	96.68	94.36	97.81	98.97	99.29	99.55

Mineral Analyses: biotite = 1, 2, 3; chlorite after biotite = 4; stilpnomelane after biotite = 5; muscovite = 6, 7; apatite in plagioclase = 8; topaz = 9; alkali feldspar (perthitic) = 10; plagioclase = 11.

Plagioclase is invariably unzoned (Fig. 2a) and of albitic composition (Ab_{98-100}, Fig. 2b). Alkali feldspar is perthitic in texture and, therefore, the average composition of Or_{96} Ab_4 (Fig. 2c) records the subsolidus re-equilibration of this phase. Muscovite has high Fe (7-12 wt. % FeO) and F (avg. 2.73 wt. %), contrasting with micas found in the greisen zones at East Kemptville (Figs. 2d, e), and with granites and greisens in the SMB (Ham and Kontak, 1988). Trace element analyses (average of 2 analyses in ppm) of muscovite from the EKL (data in Ham and Kontak, 1988) indicate enrichment in Li (6500), Rb (5850), Nb (142), Cs (371) and W (83) with low values for Be (20), Sr (42), Mo (2), Pb (8) and Th (8). REE patterns and trace element data distinguish these micas from those in the greisens at East Kemptville (see Ham and Kontak, 1988). Biotite, previously considered to be absent in the EKL, has been observed as rare (12 grains in over 100 sections examined), small (100-200 µm), subhedral grains preserved in coarse quartz and feldspar phases. It is characterized by low TiO_2 (<1.2 wt. %), MnO (<0.4 wt. %) and MgO (0.3-0.6 wt. %) contents (cf. biotite in the SMB; Allan and Clarke, 1981), and a range of SiO_2 (39-47 wt. %) and FeO (14-25 wt. %) contents. Fluorine contents increase (2.2 to 4.5 wt. %) with increasing Si and decreasing Fe. Biotite was possibly an early crystallizing phase that became unstable in later melts. It is commonly altered to chlorite and stilpnomelane (see Table 1; analyses 4 and 5, respectively). Topaz is uniform in its composition and no zoning was detected. Apatite, occurring as a secondary phase in plagioclase, is characterized by zonation of Mn (cores enriched), an inverse relationship between Ca and Mn, and F contents of 2.4 - 4.0 wt. %.

GREISEN CHEMISTRY

As part of the mapping project of the East Kemptville deposit (Kontak et al., 1986) a suite of about 200 samples, including EKL and a variety of greisen

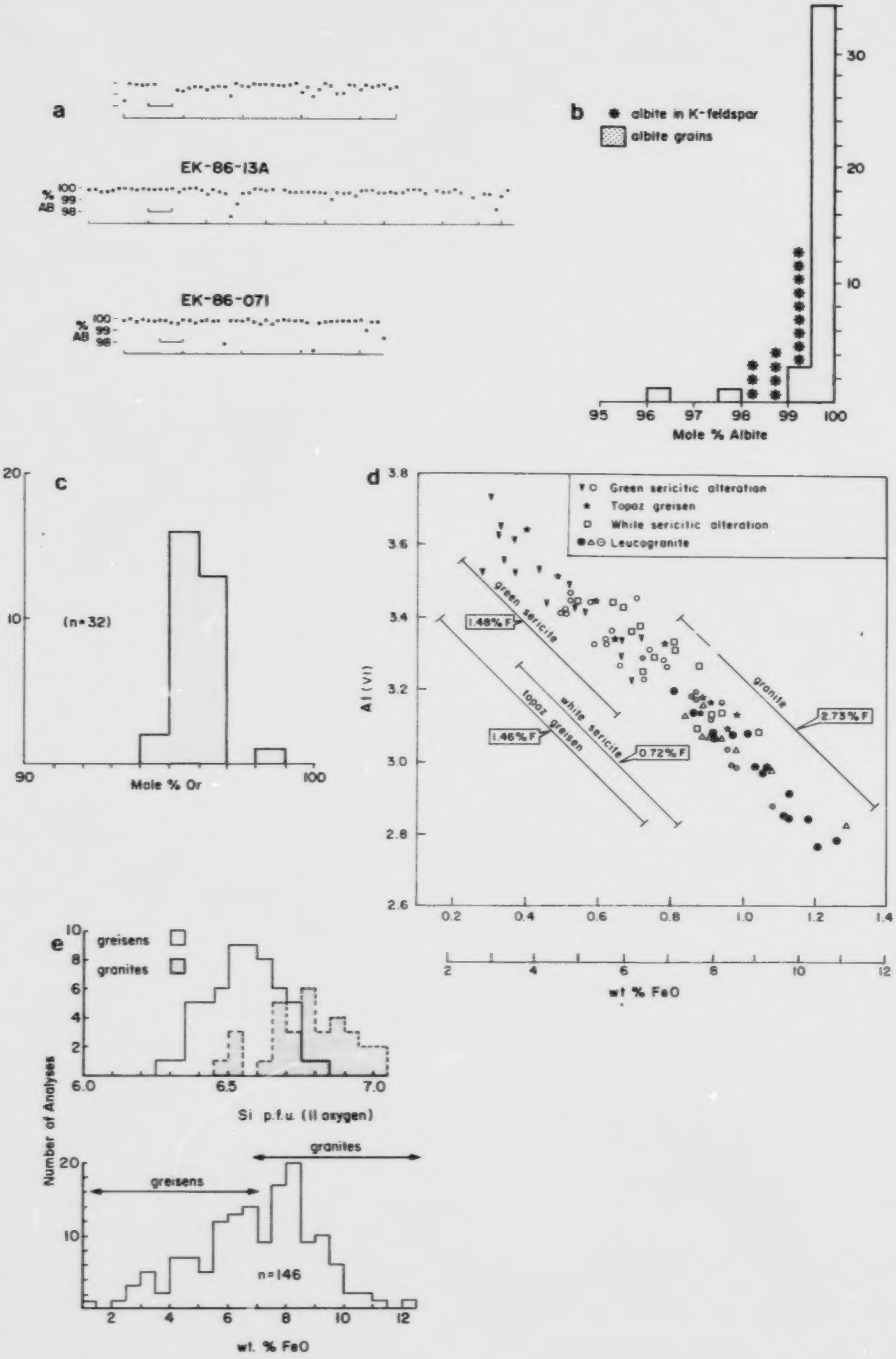


Figure 2. Chemistry of different mineral phases in the EKL: (a) traverses of plagioclase grains in EKL (analyses every 10 um); (b) histogram of analyses of plagioclase in the EKL occurring as perthitic lamellae in alkali feldspar and discrete grains; (c) histogram of analyses of plagioclase perthitic alkali feldspar; (d) Al(iv) versus FeO and Fe (calculated for 11 O atoms); (e) histograms for Si and wt. % FeO for muscovite in the EKL and greisens at East Kemptville.

types (Kontak et al., 1986), was collected on a grid system (one sample per 100 m^2) to provide a chemical database for examining the elemental patterns and zonation within the deposit. In addition, a variety of greisens have been selected from ore piles to complete coverage of the lithologies present in the deposit. Representative analyses of greisens are presented in Table 2. The following is a summary of some of the results, a more detailed study of the data is in preparation.

Bivariate plots of some of the more relevant elemental associations are presented in Figure 3; included on the diagrams are the average values for ore mined at the deposit and bulk analyses of Ford and O'Reilly (1985) and Chatterjee et al. (1985). The data indicate that the material being mined represents a mixture of a variety of rock types, notably very high-grade greisens and veins (i.e. about 25-30 wt. % Sn; see Table 2), low-grade greisens (about 0.1-0.5 wt. % Sn), and sub-ore grade material (about <<0.1 wt. % Sn). Although the bulk of the data indicate a weak positive correlation between Sn and Cu (Fig. 2b), these elements were deposited during separate paragenetic stages (Kontak et al., 1988a; Richardson et al., 1982). The most consistent relationship observed is the negative correlation between Sn and combined alkalis (Fig. 2f), which reflects the destruction of the feldspar phases in alteration zones

Table 2. Representative analyses of dark greisens, East Kemptville.

	73	90	044	150	89	123B	76B	017	057	120B
SiO_2	71.69	68.73	74.15	66.23	73.53	76.75	70.63	46.71	50.47	28.75
TiO_2	0.00	0.00	0.01	0.01	0.01	0.03	0.01	0.02	0.02	0.05
Al_2O_3	12.55	16.07	14.91	13.40	14.58	12.08	13.45	16.48	12.60	43.38
Fe_2O_3	5.09	4.88	1.74	7.29	3.55	3.13	2.45	1.72	5.66	3.53
MnO	0.09	0.01	0.00	0.09	0.02	0.08	0.04	0.04	0.18	0.06
MgO	0.02	0.01	0.01	0.07	0.00	0.35	0.03	0.03	0.05	0.06
CaO	0.56	0.64	0.55	0.81	0.47	0.81	0.32	0.32	2.61	0.17
Na_2O	0.02	0.01	3.75	0.22	0.33	2.57	0.46	0.16	0.17	0.31
K_2O	0.48	0.29	4.02	3.74	0.21	0.35	1.55	0.82	1.08	1.90
P_2O_5	0.36	0.16	0.40	0.53	0.51	0.55	0.30	0.22	3.05	0.46
LOI	2.80	3.60	1.23	3.07	2.29	0.84	1.20	1.18	3.33	1.63
F	2.19	2.02	1.15	1.02	3.85	1.83	2.90	1.66	0.62	3.63
C	0.13	0.18	-	-	0.028	-	0.075	0.017	0.047	0.037
B	10	<10	-	-	-	-	-	-	-	-
Li	238	38	-	579	850	-	488	172	378	542
Zn	3934	3439	634	1497	256	4944	886	5818	14886	658
Cu	6045	1858	895	4968	750	320	2291	2802	1902	11288
Pb	853	2554	1083	4672	1169	526	17056	7%	39587	34344
Sb	0.6	0.4	0.3	1.8	0.2	-	0.3	0.6	0.5	0.5
Ag	20	<5	-	-	<5	-	<5	5.5	<5	22
As	6	3	7	14600	14	-	3	82	72	138
Au	<5	<5	5	<19	<5	-	<5	<16	<11	<5
Ba	9	6	11	34	6	12	8	10	14	11
Rb	204	86	970	1259	44	1040	461	280	491	655
Sr	37	27	22	63	30	29	57	161	261	117
Ga	9	6	37	46	7	40	20	26	31	21
Nb	36	82	38	58	27	27	109	528	282	219
Zr	27	28	28	18	30	35	26	26	25	12
Y	8	1	35	33	9	24	17	9	31	18
U	26	22	23	17	24	-	24	<10	20	30
Th	6.0	4.2	5.0	6.0	4.8	-	5.1	2.8	6.6	6.7
Sn	3154	8047	2000	12000	3100	-	4.9%	25%	11.4%	10.5%
W	62	31	79	1630	16	-	150	804	221	130
Cs	12	5	45	43	3	-	26	11	28	36
Mo	10	5	7	<4	5	-	<2	<8	<6	21
Ta	9	13	15	21	11	12	14	123	49	29
Cd	44	46	<10	<30	<10	69	13	44	160	<10

Note: All trace elements in ppm except for Au (ppb) and Sn (wt. %) where noted.

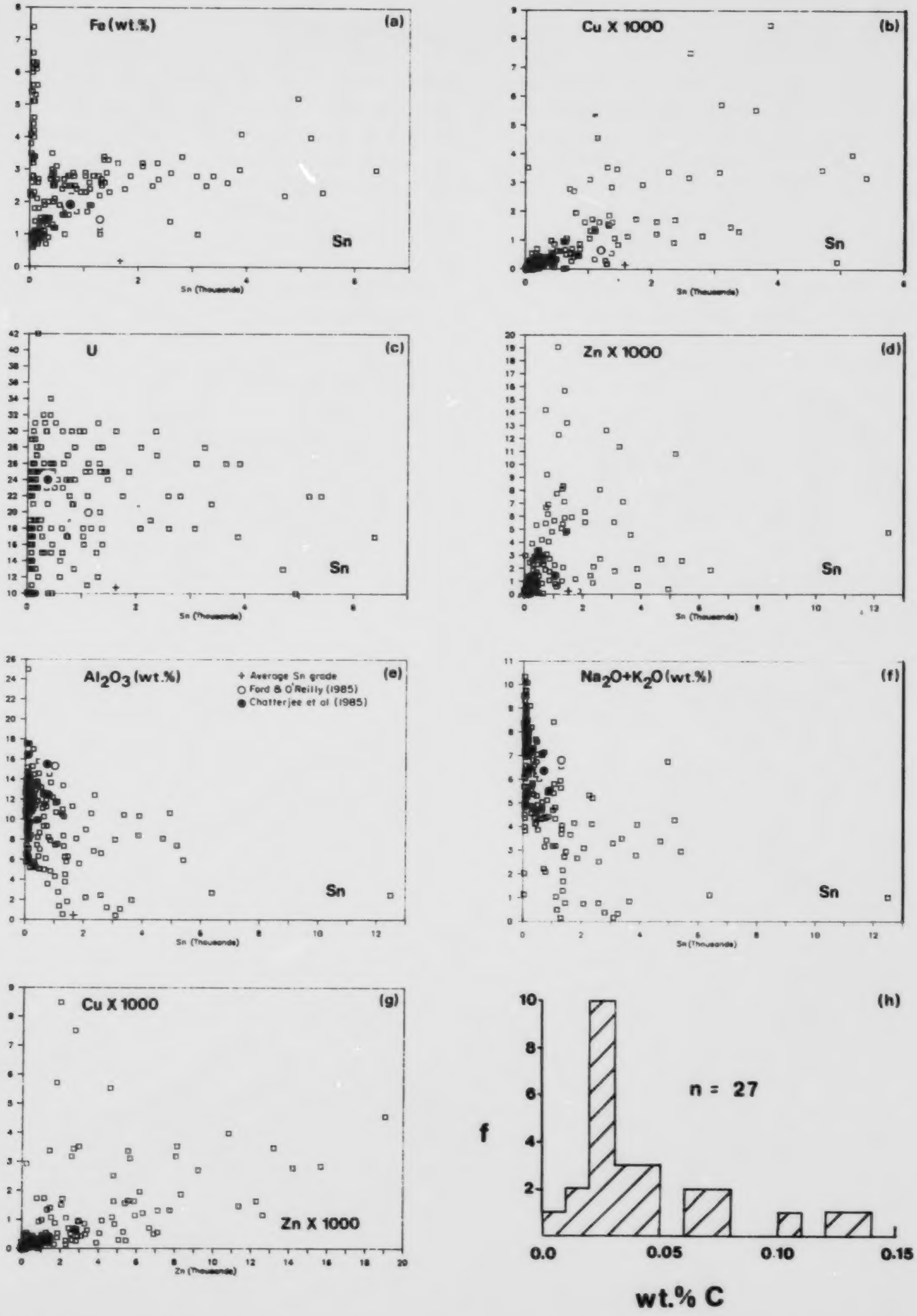


Figure 3. Geochemical data for the greisens at East Kemptville. All the data are for samples collected from the northern part of the deposit mapped by Kontak et al. (1986). Note that higher grade samples (i.e. up to 25-30 wt. % Sn) have been omitted for purposes of plotting and that the scale on the ordinate in Figures a to f changes to accomodate the spread of data.

containing cassiterite. Analyses of other elements (in ppm) from the grid samples, of particular relevance to tin mineralizing systems, include the following: (1) Ag present in amounts of about 100; (2) Sb consistently low at <10; (3) Pb generally <100-200, with one analysis >7000; (4) Bi in the 30-100 range; (5) Cd may run 100-150 with values <5 for the EKL; (6) Ba is often several hundred and sometimes >1000, despite low abundances (i.e. 40 ppm) in the EKL; (7) Mo consistently <10-15; (8) Li runs 100-1300 and reflect[illegible]e amount of mica present (see above); (9) W runs <50 and only gets high (up to >1000) in Sn-rich samples; and (10) Rb, Zr, Nb, Y and Ga are at or below levels found in the EKL (Kontak, 1987a) indicating that they are generally diluted to lower abundances by the mineralizing process.

Graphite was detected in the dark greisens as fine, amorphous, irregular concentrations intimately associated with sulphide minerals. Analyses of several of these samples confirmed the presence of carbon (0.01 to 0.14 wt. % C, Fig. 3h).

STABLE ISOTOPIC DATA FOR VEIN ASSEMBLAGES

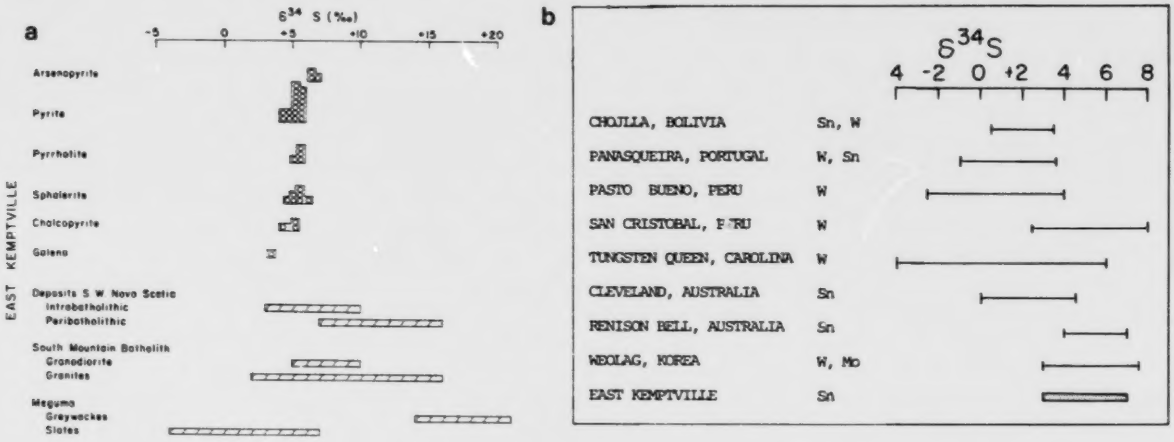
Stable isotopic data provide important information with respect to the source reservoirs of the fluids, metals and anions (e.g. S) involved in mineralizing processes and the physiochemical conditions attending the event. Detailed discussions of the applications of these methods are found in Faure (1977), Ohmoto and Rye (1979), Kyser (1987) and Valley et al. (1986).

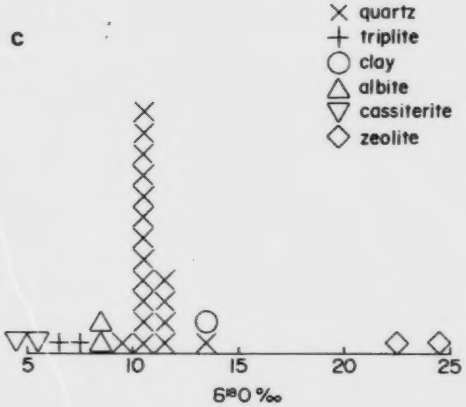
SULPHUR

Sulphur isotopic data obtained for sulphides (pyrite, pyrrhotite, sphalerite, arsenopyrite, galena, chalcopyrite) from all paragenetic stages indicate a very constant $\delta^{34}S$ value of about 5 ± 1‰ (Fig. 4a). The data overlap the range for intrabatholithic deposits of southwest Nova Scotia (Chatterjee, personal communication, 1987), and also overlap values for the SMB and some Meguma Group metasedimentary rocks (Kubilius, 1983). In Figure 4b the data are compared with a number of world-class Sn and W deposits; East Kemptville corresponds to the more positive end of the range for $\delta^{34}S$. Conflicting interpretations have been offered concerning the S source for these high values of $\delta^{34}S$ (i.e. magmatic versus sedimentary), however because the data herein do not overlap values for the peribatholithic deposits of the SMB (Fig. 4a) or the metamorphogenic vein gold deposits of the Meguma Terrane (9-25‰; Kontak and Smith, in press), a magmatic source is presently favoured for sulphur at East Kemptville.

OXYGEN

Oxygen isotopic data have been obtained for mineral phases from all paragenetic stages (Fig. 4c). Quartz is present in all stages and, therefore, several analyses of this mineral are presented; it is remarkably uniform with a slightly enriched value for the cassiterite stage versus subsequent stages (i.e. $\delta^{18}O$ = 11.4‰ versus 10.5‰, respectively). The composition of the fluid for each mineralizing stage has been calculated using the results of analyses, temperatures obtained from fluid inclusion studies, and the appropriate mineral-water fractionation equation (see Kyser, 1987). The results (Fig. 4d) indicate a range for $\delta^{18}O_{fluid}$ of about 6.5‰ to 3.0‰ for mineralization with values becoming progressively lighter from early to late stages of mineralization. As these results are preliminary and deuterium isotopes are required before a more conclusive interpretation can be offered, a dominantly magmatic source is only cautiously suggested.





d

Stage	Mineral	δ18O	δ18O fluid	T°C	n
Cass	Qtz Cass	11.2-11.5 8.1-8.8	6.2-6.9 11-12	350 350	2 2
Sulp	Qtz	9.9-11.1	3.0-4.2	300	10
	Qtz	9.9-10.9 8.1-8.8 6.4-7.1	3.0-4.0 2.8-3.5 —	300 300 —	4 2 2
Clay	Kaol	13.8	2.8 7.6	150 250	1 1

Figure 4. Stable isotopic data for greisens and veins at East Kemptville: (a) S isotope data for vein and greisen sulphides compared to data from deposits of southwest Nova Scotia (unpublished data of Chatterjee, personal communication, 1987), and granites of the SMB and Meguma Group metasedimentary rocks (Kubilius, 1983); (b) S isotopic data for East Kemptville deposit compared to data from other Sn and W mineralized centres; (c) O isotopic data for vein and greisen minerals; (d) calculated $\delta^{18}O$ values of the mineralizing fluid for different stages using mineral-water fractionation equations (Kyser, 1987) and inferred temperatures for different paragenetic stages (obtained from fluid inclusion studies).

FLUID INCLUSION STUDIES

Fluid inclusion chips were prepared for all rock types at East Kemptville, including the EKL, various greisens and all vein stages. The overprinting shear deformation (Kontak et al., 1986; Kontak, 1987a) has, however, caused extensive recrystallization of all lithologies and consequently the quality of the material varies considerably. To date reliable data have not been obtained for the EKL and the richly mineralized (i.e. tin) topaz greisens. Instead, the best data are for the main sulphide stage and the subsequent albite-phosphate stage.

FLUID INCLUSION PETROGRAPHY

The EKL contains small (<10 μm) supersaturated inclusions, hosted by quartz, that are characteristically multiple phase types containing aqueous brine, vapour, halite, sylvite and unknown solids. All other material (i.e. veins) contains two-phase (liquid plus vapour) fluid inclusions, except for the rare presence of halite and an unidentified birefringent solid. In late albite-phosphate veins halite is a ubiquitous third component. Fluid inclusions in the sulphide and albite-phosphate stages are typically 10-50 µm in diameter, generally negative shaped, and mostly of pseudosecondary origin.

THERMOMETRIC DATA

Results of heating experiments for 4 samples are presented in Figure 5 along with a composite of the 506 measurements. There are three distinct peaks at about 280-300°C, 230-250°C and 180°C, which correspond to sulphide and albite-phosphate, fluorite, and clay depositing events, respectively. In some cases (e.g. samples 111.2 and 055) a single fluid event of restricted temperature dominates, whereas two and possibly three distinct fluids of differing temperatures passed through the remaining two samples.

Freezing data are currently being acquired, but preliminary results indicate that most of the sulphide stage fluids contained <10 wt. % equivalent NaCl with 25-30% typical of later barren veins of the albite-phosphate stage. Minor amounts of CO_2 are present and melting temperatures of this phase (-59° to -56°C) also indicate the presence of CH_4.

DISCUSSION

While studies at East Kemptville continue, work thus far indicates that a specialized topaz granite, probably generated in a ductile shear zone (Kontak, 1987a, c), hosts greisen-style tin and base metal mineralization which evolved in an environment dominated by magmatic-derived fluids based on O and S isotopic data. The mineralization is not disseminated throughout the deposit, as indicated by Richardson et al. (1982), but is instead concentrated in moderate- to high-grade greisens (Kontak et al., 1986). The ore grade of 0.165% Sn represents dilution of this mineralization by lower grade material, including a large amount of the EKL (Fig. 3).

Fluid inclusion data indicate that the main sulphide stage was deposited from high temperature (about 300°C; not pressure corrected), moderately saline brines that contained minor CO_2-CH_4, consistent with the presence of graphite in the dark, mineralized greisens. Data for the cassiterite stage remain to be obtained. S isotopes indicate a probable magmatic source, as all paragenetic stages have $\delta^{34}S$ values of 5 ± 1°/.., while O isotopes indicate $\delta^{18}O_{fluid}$ of about 7 - 3°/.. from early to late stage mineralization.

Similar data to those presented herein for mineralization at East Kemptville remain to be acquired for mineralized centres in the SMB and, therefore, it is not possible at present to draw comparisons.

ACKNOWLEDGMENTS

Chemical analyses were obtained at Technical University of Nova Scotia, Halifax (whole rock) and Dalhousie University, Halifax (electron microprobe) with the capable assistance of Mr. C. Coyle and Mr. B. McKay, respectively. Rare earth element data were provided by Drs. R. P. Taylor (Carleton University) and J. Dostal (St. Mary's University), while the stable isotopic data were obtained with the assistance of Drs. R. Kerrich (University of Saskatchewan) and C. McMullen (McMaster University); the cooperation of all these people is sincerely appreciated. Dr. D. B. Clake kindly reviewed the manuscript and provided stimulating discussion.

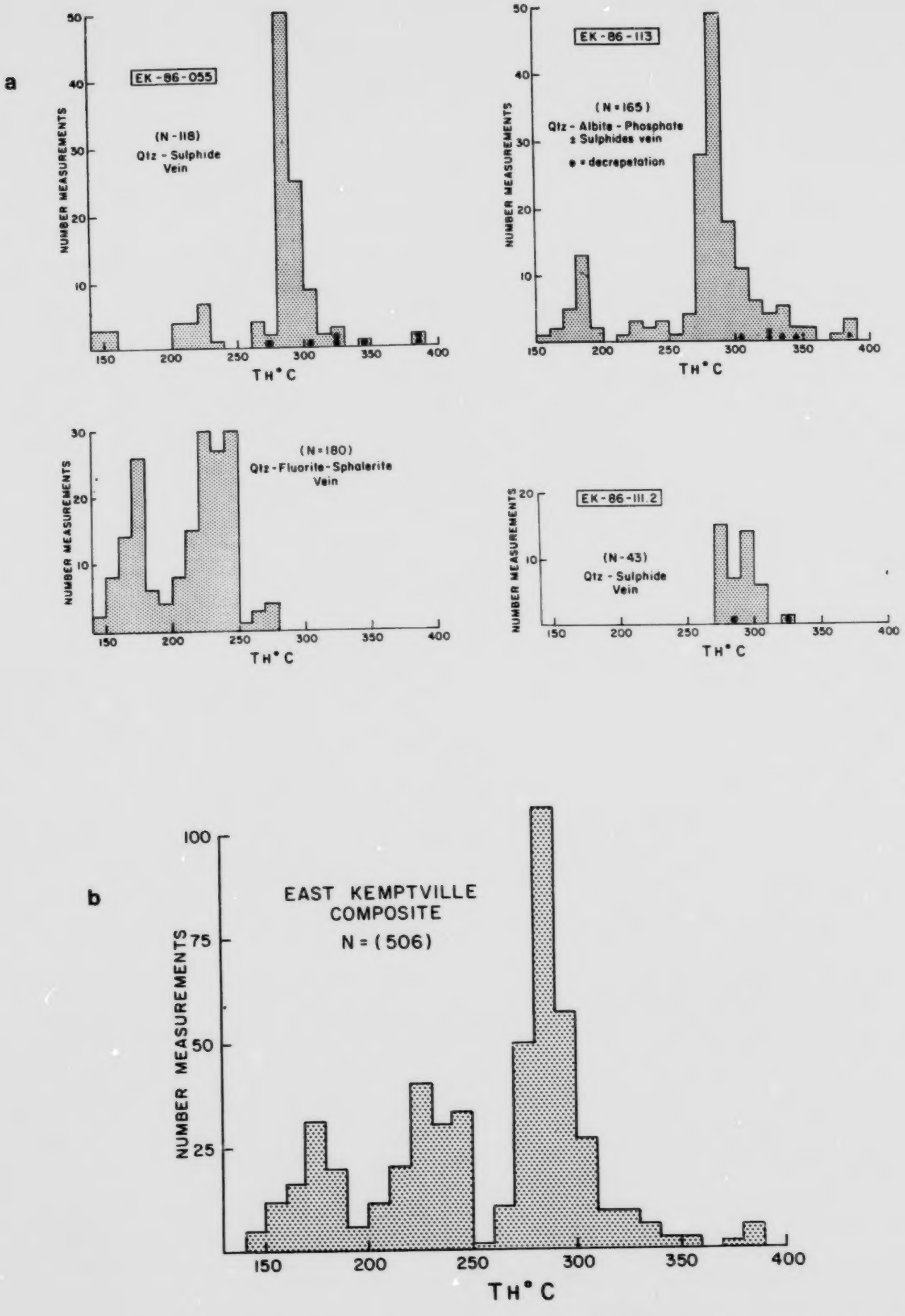


Figure 5. Histograms of homogenization temperatures for fluid inclusions in different vein minerals from East Kemptville.

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METAMORPHISM OF MEGUMA GROUP METASEDIMENTS - CONTACT AUREOLES[1]

S. L. Douma

INTRODUCTION

The purpose of this project is to document the contact and regional metamorphic history of the Meguma Group in eastern Nova Scotia. The project is part of an ongoing study of metamorphic parameters relevant to gold mineralization.

Preliminary work has focused on the metamorphic mineral assemblages and associated mineral chemistries in the contact aureoles of the two largest granitic bodies in the Meguma Zone (the South Mountain Batholith (SMB) and the Musquodoboit Batholith) (see sample location map, Douma, 1988). Comparisons are made between metamorphic mineral chemistries associated with these contact aureoles and similar regional metamorphic assemblages.

The eastern Meguma Group metasediments consist of psammite, pelite, calcsilicate and manganiferous lithologies that were subjected to several metamorphic episodes. Earlier mapping of chlorite, biotite, garnet, andalusite-cordierite-staurolite and sillimanite zones (Muecke, 1984) shows that critical mineral assemblages indicate low-medium pressures and high temperatures (peak conditions: P_{total} = 3.5-4.5 kbar; 650° C).

OBSERVATIONS

SOUTH MOUNTAIN AND MUSQUODOBOIT BATHOLITH CONTACT AUREOLE ASSEMBLAGES

Characteristic metamorphic mineral assemblages associated with pelitic horizons in the SMB and Musquodoboit Batholith aureoles are very similar. They include: biotite, muscovite ± plagioclase ± K-feldspar ± cordierite ± andalusite ± chlorite ± tourmaline (Table 1). The biotite, muscovite, cordierite and andalusite are associated with a prograde thermal metamorphic event. The chlorite is typically retrograde and is formed at the expense of biotite and cordierite. The cordierite is anhedral, commonly altered to pinite, appears unstable relative to andalusite, is ragged, sericitized and embayed, and contains abundant inclusions. The cordierite commonly developed prior to the growth of the andalusite porphyroblasts. Andalusite is less altered than the cordierite but is often sericitized.

Current mapping does not allow differentiation of metamorphic contact zones within the South Mountain Batholith and the Musquodoboit Batholith aureoles. Hornfelsic textures predominate in pelitic horizons up to 100 m from the contacts with the SMB and the Musquodoboit Batholith.

The highest grade assemblage associated with the SMB aureole is

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[1] Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

	SAMPLE NO.	ROCK TYPE	DISTANCE	BIOTITE	MUSCOVITE	GARNET	FELDSPAR	AMPHIBOLE	EPIDOTE	CALCITE	SPHENE	ANDALUSITE	CORDIERITE	TOURMALINE	RUTILE	CHLORITE	PYROXENE
MUSQ	11D-D-087	PELITE	0.80 KM		X						X		ALT			X	
	11D-D-006	PELITE	0.05 KM	X										X			
	11D-D-098	PELITE	0.70 KM	X	X											X	
	11D-D-155	PELITE	1.40 KM										ALT ?			X	
	11D-D-112	PELITE	0.25 KM	X	X								X	X			
	11D-D-157	PELITE	1.40 KM		X								X	TR			
	11D-D-004	PELITE	0.70 KM	X	X		OLIG						ALT ?	X	X		
	11D-D-118	METASILT	0.50 KM	X	X											X	
	11D-D-005	SEMI-PEL	0.25 KM	X	X		KSP							X			
	11D-D-086	METAGREY	0.80 KM	X	X									X			
	11D-D-097	METAGREY	0.80 KM	X	X						X			X		X	
	11D-D-119	METAGREY	0.50 KM	X	X									X		X	
	11D-D-153	METAGREY	0.80 KM		X											X	
	11D-D-085	METAGREY	0.80 KM	X						X			ALT			X	
	11D-D-120	METGR/SIL	0.05 KM	X	X						X	X	X	X		X	
	11D-D-156	PSAMMITE	1.40 KM	TR	X								X	X			
	11D-D-088	PSAMMITE	0.65 KM	X	X		ORTH								X	X	
	11D-D-006	CALCSIL	0.05 KM			X	TR PL.KSP	X	X	X	X						X
	11D-D-007	CALCSIL	0.25 KM			X		X	X	X							X
	11D-D-121	OP-SHALE	0.50 KM	X	X												
	MLD87-1	OP-SHALE	0.50 KM	X	X												
SMB	11D-D-041	PELITE	0.05 KM	X	X							X	X				
	11D-D-042	PELITE	0.05 KM	X								X	X		X	X	
	11D-D-178	PELITE	1.00 KM	X	X		X						X			X	
	11D-D-126	PELITE	0.75 KM	X	X		X						X				
	11D-D-127	PELITE	0.50 KM	X	X								X				
	11D-D-196	PELITE	1.20 KM	TR	X							X	X	X	TR	X	
	11D-D-103	SEMI-PEL	0.10 KM	X	X												
	11D-D-105	SEMI-PEL	0.35 KM	X	TR		X						X			X	
	11D-D 038	PEL/GREY	1.00 KM	X	X		X					X	X				
	11D-D-106	METAGREY	0.35 KM	X	X								ALT ?				
	11D-D-104	METAGREY	0.05 KM	X	X		X								X	TR	
	11D-D-108	PSAMMITE	1.80 KM	X	X									X		X	
	11D-D-040	CALCSIL	0.30 KM		X	X		X	X		X					X	X
	11D-D-043	CALCSIL	0.75 KM		X	X	X	X	X	X	X				X	X	
	11D-D-101	MN-SHALE	1.80 KM														
	11D-D-051	COTICULE	1.20 KM		X	X											
	11D-D-102	COTICULE	1.00 KM		TR	X	X										
	11D-D-052	COTICULE	1.20 KM	X		X	X									X	
	11D-D-050	COTICULE	1.20 KM			X									X	X	

SMB- South Mountain Batholith contact aureole
MUSQ- Musquodoboit Batholith contact aureole
Rock Types:
METAGREY- metagreywacke
CALCSI- calcsilicate lens
MN-SHALE- manganese-rich shale
OP-SHALE- opaque-rich shale
PEL/GREY- finely interbanded pelite and metagreywacke
SEMI-PEL- semi-pelite

DISTANCE- distance in kilometres to the nearest contact with the granitic intrusion
TR- trace amounts of mineral
ALT- altered
?- uncertain identification of mineral (due to severe alteration)
OLIG- oligoclase
KSP- K-feldspar
ORTH- orthoclase
PL- plagioclase
X- Mineral present

Table 1. Mineral assemblages associated with the South Mountain Batholith contact aureole and the Musquodoboit Batholith contact aureole.

cordierite, biotite, muscovite, andalusite ± plagioclase ± K-feldspar. Similar peak temperature assemblages are associated with the Musquodoboit aureole and although no andalusites were observed in samples collected during this study, reported occurrences have been made by Kontak (personal communication, 1988). The pressure at which peak metamorphic assemblages equilibriated may be inferred for both aureoles assuming that andalusite grew at the expense of muscovite and cordierite (based on textural evidence). The relevant reaction is: 2 muscovite + 3 cordierite - 7 quartz + 8 andalusite + 2 biotite + 3 water (after Pattison and Harte, 1985). Pressures for this assemblage are between 2.4 kbar and 3.5 kbar (Hope, 1987, Fig. 23, p. 96).

Four lithologies within a distance of 2 km from the SMB were sampled for mineral analyses. They include: pelite, metagreywacke (+ semi-pelite), coticule horizons and calcsilicate lenses. Four lithologies were also sampled within the Musquodoboit Batholith contact aureole (within 1.5 km of the granite). They include: pelite, metagreywacke (+ semi-pelite), calcsilicate lenses and opaque-rich shales. Table 2 summarizes a few mineralogical and petrological features of both the SMB and the Musquodoboit Batholith contact aureoles.

Chlorite and biotite (Fig. 1) (sensitive indicators of pressure, temperature, host-composition, etc.) analyses results were used as a means of comparing the mineralogical chemistry of the two contact aureoles with different grades of regional metamorphism and gold-deposit environments in the eastern Meguma Group (Figs. 2 and 3). Amphibolite and biotite zones are used to represent two grades of regional metamorphism in the eastern Meguma Group and the Beaver Dam gold deposit (Kontak and Smith, 1988) is used to represent a typical gold deposit setting. Chlorites from lithologies associated with the regional metamorphism (biotite and amphibolite zones) are comparable in composition to those associated with the Musquodoboit aureole but are depleted in Fe^{2+} and $^{3+}$ relative to those associated with the SMB aureole. The chlorites within the veins associated with the Beaver Dam deposit (Kontak and Smith, 1988) are depleted in Fe^{2+} and $^{3+}$ compared to chlorites associated with contact or regional metamorphism. Considerable overlap in composition occurs in biotites associated with regional metamorphism and those associated with contact metamorphism (Fig. 3). Biotites associated with veins in the Beaver Dam gold deposit are depleted in Al^{iv} and Fe/(Fe+Mg) relative to the regional or contact metamorphic biotites from pelitic horizons.

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Table 2. Comparative mineralogical features and assemblages observed in contact aureoles associated with the South Mountain Batholith and the Musquodoboit Batholith.

SOUTH MOUNTAIN BATHOLITH	MUSQUODOBOIT BATHOLITH
LITHOLOGIES ANALYZED:	
Samples collected within 2 km from contact; pelite, metagreywacke (and semi-pelites) coticule horizons, calcsilicate lenses.	Samples collected within 1.5 km; pelite, metagreywacke (and semi-pelite), calcsilicate lenses, and opaque-rich shales.
BIOTITES:	
Compositions are controlled by the four host-rock lithologies (Fig. 1). Pelites contain biotites whose mineral chemistries are more varied than those associated with the Musquodoboit aureole (Fig. 3). Biotites within the pelitic layers are typically enriched in Fe/(Fe+Mg) with respect to the pelitic layers associated with the Musquodoboit Batholith.	Compositions similar in pelites, metagreywackes and semi-pelites. The opaque-rich shales have a lower Fe/(Fe+Mg):Ti ratio, a low Al^{iv} (2.35-2.55) and low Fe/(Fe+Mg) (0.47 - 0.53) compared to those in the pelites (2.45 - 2.89:0.47 - 0.62), metagreywackes (2.5 - 2.9: -.45 - 0.64) and calcsilicate lenses (2.49 - 2.62: 0.57-0.61) (based on 24 oxygens). Biotites associated with calcsilicate lenses have slightly higher (Fe/(Fe+Mg):Ti ratios, Al^{iv} and Fe/(Fe+Mg) values than the pelites and metagreywackes.
MUSCOVITES:	
Compositions are apparently not controlled by the host-rock. There is considerable overlap in composition for all lithologies analyzed. Na/(Na+K) range from 0.02 - 0.17 and A^{iv} range from 1.4 - 2.1 (based on 24 oxygens).	Muscovites associated with pelites and metagreywackes have similar compositions (range Na/(Na+K) = 0.025-0.28; Al^{iv} = 1.20 - 1.95). Muscovites associated with the opaque-rich shales have low Na/(Na+K) ratios (0.025-0.04).
CHLORITE:	
Prograde chlorite is not abundant in any of the lithologies analyzed and appears as a retrograde mineral after biotite, garnet and cordierite. Compositions range from pseudothuringite to ripidoite to brunsvigite (Fig. 2) (nonmenclature after Hey, 1954). The chlorites are enriched in Fe^{2+} and $^{3+}$ with respect to those associated with the Musquodoboit aureole.	Prograde chlorite is not abundant. Retrograde chlorite has similar habit to chlorite associated with the SMB contact aureole. Compositions range from pseudothuringite, brunsvigite and sheridanite (Fig. 2) (nomenclature after Hey, 1954).

PYROXENE:

Identified only in the calcsilicate lenses. Only traces of pyroxene observed in a calcsilicate lens 300 m from the contact with the batholith. Composition of pyroxene is hedenbergite. It is intimately associated with epidote.

Hedenbergite associated only with calcsilicate lenses. Hedenbergite identified in two samples collected less than 50 m from contact and 250 m from the exposed contact of the batholith.

CORDIERITE:

Observed in samples collected from within 1 km (typically within 400 m) of the exposed contact with the batholith. Analyzed cordierites have low total (average 88%) suggesting than they are extensively altered.

Fe/(Fe+Mg) ratios range from 0.30-0.68 (on 18 oxygens).

Observed in samples collected from within 1.4 km (typically within < 800 m of the exposed contact with the batholith). The cordierite totals are low (average 92%). They are altered by muscovite and chlorite. Fe/(Fe+Mg) range from 0.39 - 0.70 (based on 18 oxygens).

TOURMALINE:

Tourmaline is associated with pelites and metagreywackes. Both detrital and secondary minerals were observed. No microprobe analyses done to date.

Tourmaline is associated with pelites and metagreywackes. Both detrital and secondary tourmaline are associated with these lithologies. Secondary and primary tourmalines can not be differentiated chemically. Both range in composition between schorl (Fe-rich) and dravite (Mg-rich) (nomenclature after Hess, 1954).

OPAQUE MINERALS:

Ilmenite, rutile, fe-oxides and fe-sulphides are associated with all lithologies analyzed.

Ilmenite, rutile, fe-oxides, and fe-sulphides are associated with all lithologies analyzed.

COTICULE HORIZONS:

Horizons enriched in quartz and Mn-rich garnets. Composition of garnets:
Spess$_{50-82}$ Gross$_{6-1}$ Alm$_{5-32}$ Pyr$_{0-8-5.0}$

No coticule horizons analyzed in aureole.

CALCSILICATE LENS ASSEMBLAGES:

Qtz-gnt-clinozoisite ± hedenbergite-calcite-hb-rutile-ilmenite-fe-oxides, fe-sulphides-kspar-mu-sphene-traces of chlorite.
Range in garnet compositions:
Spess$_{5-6}$Gross$_{54-89}$Alm$_{5-8}$Pyr$_{0.3-1}$
(distance from contact <750m).

Qtz-gnt-clinozoisite-calcite ± sphene hedenbergite-actinolite (hornblende)-opaques-ilmenite-rutile-fe-oxides-fe-sulphides-pl-kspar.
Range in garnet compositions:
Spess$_{1-3}$Gross$_{56-90}$Alm$_{5-9}$Pyr$_{0.2-0.4}$
(distance from contact <250 m).

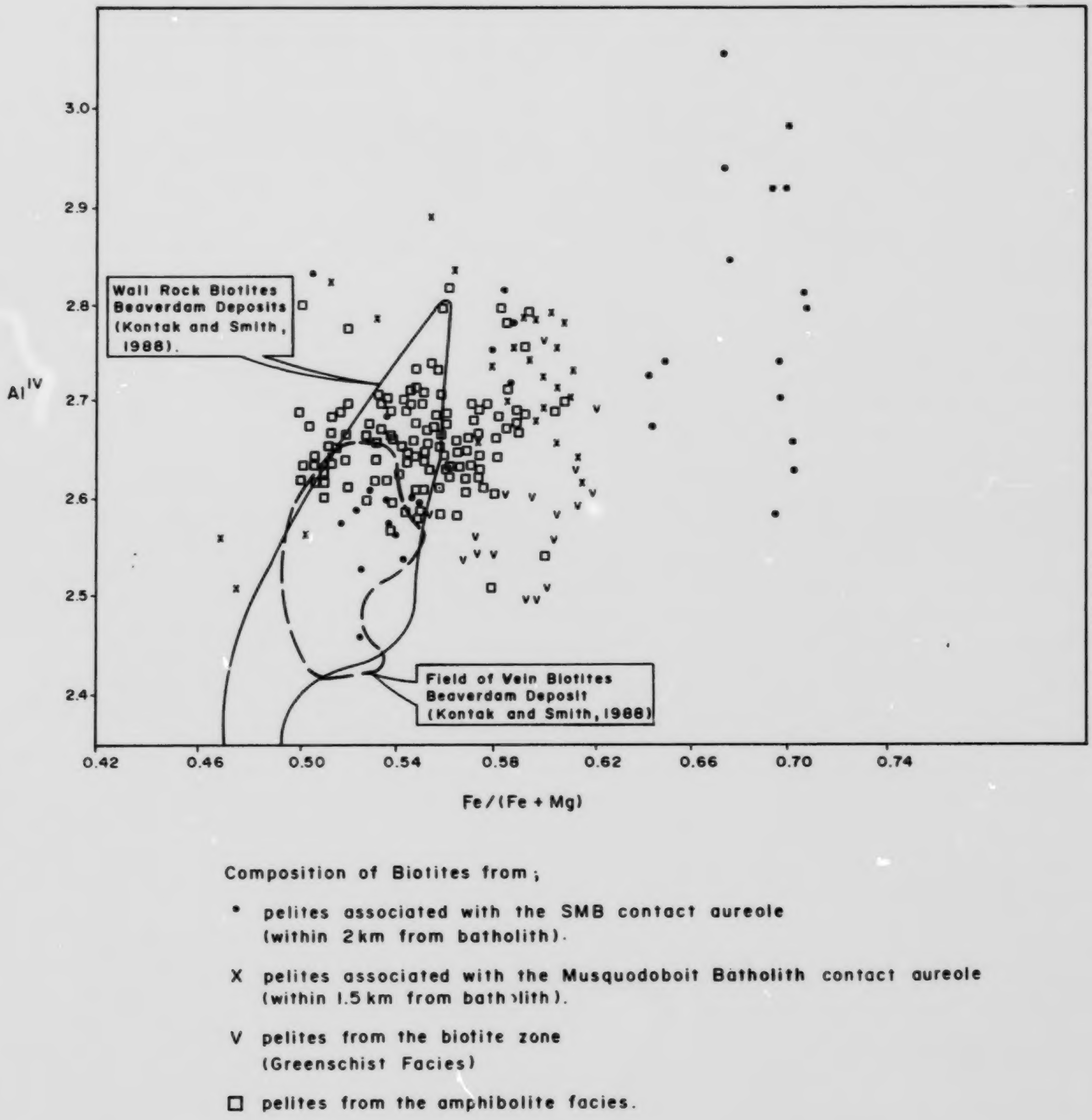

Figure 1. A comparison of biotite compositions of four distinct lithologies in the South Mountain Batholith and Musquodoboit Batholith contact aureoles. Fe/(Fe+Mg) versus Ti (recalculated based on 24 oxygens). All samples were collected from within 2 km of the contact with the SMB and 1.5 km of the contact with the Musquodoboit Batholith.

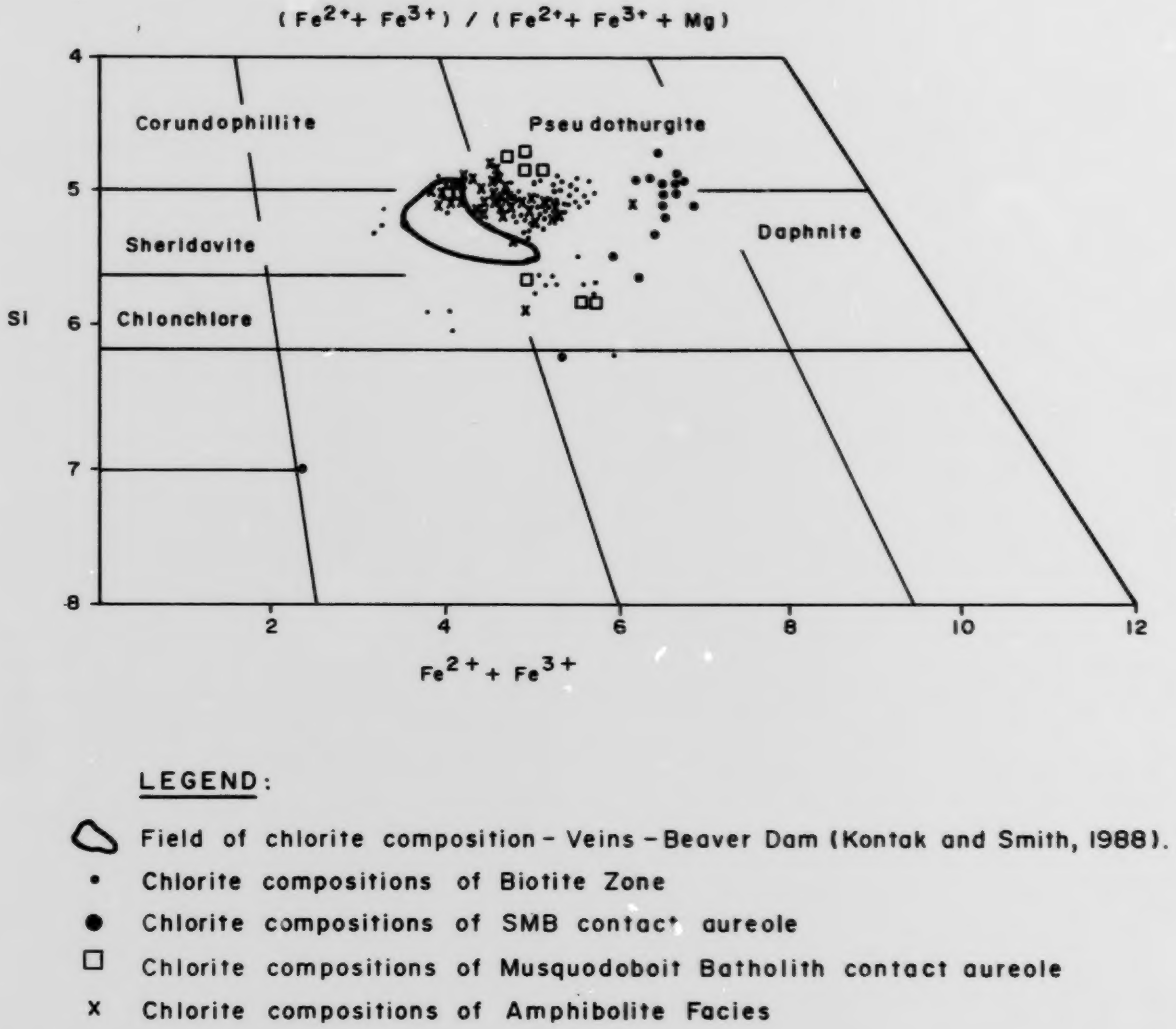

Figure 2. A comparison of the composition of chlorites in different geological settings within the Meguma Group metasediments and gold deposits.

Note: gold deposit data from Beaver Dam deposit (Kontak and Smith, 1988).

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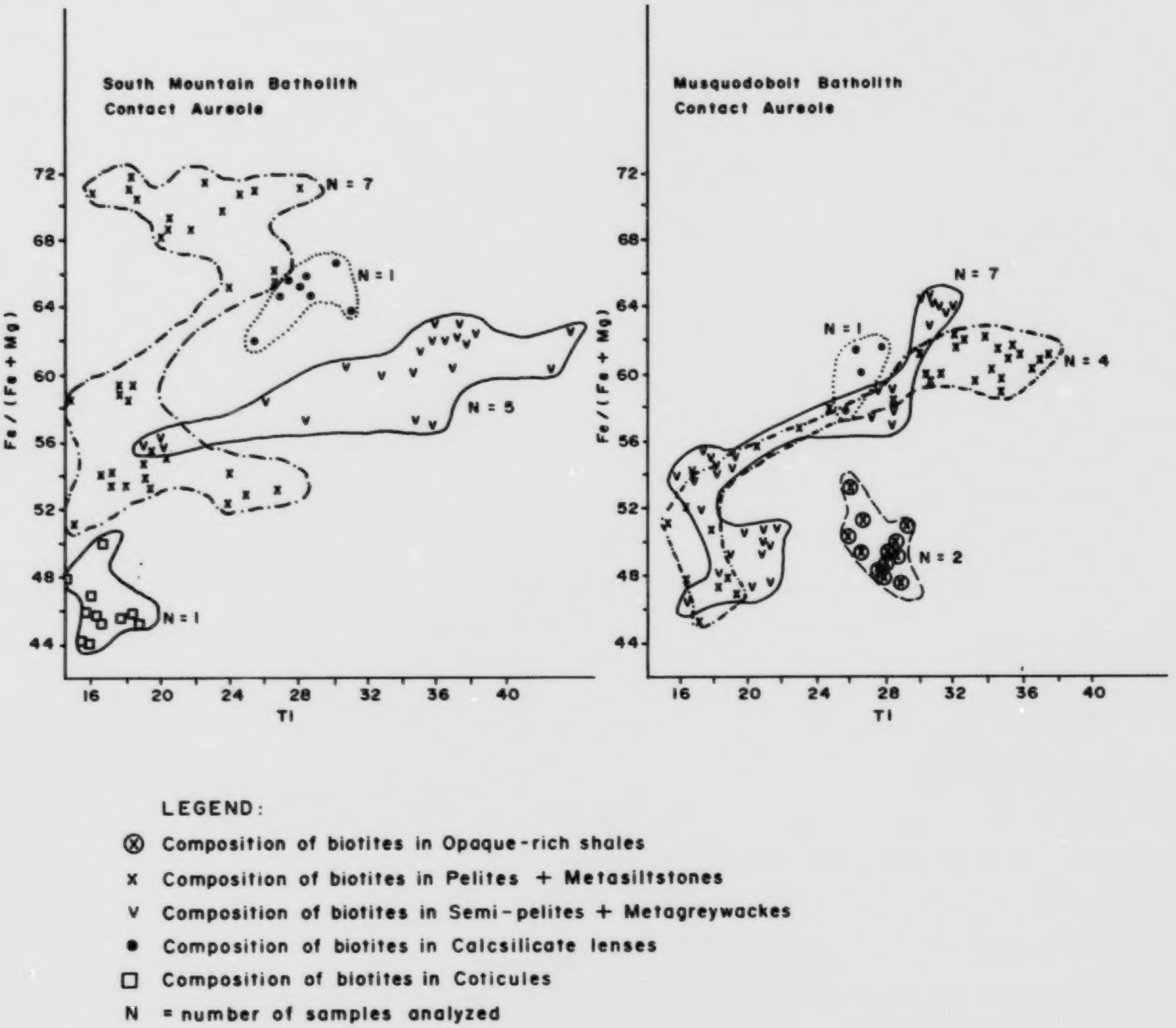

Figure 3. A comparison of the composition of biotites (from pelitic horizons) in different geologic settings within the Meguma Group metasediments and gold deposits.

Note: gold deposit data from Beaver Dam deposit (Kontak and Smith, 1988).

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SOUTH MOUNTAIN BATHOLITH PROJECT: MINERAL DEPOSIT STUDIES[1]

G. A. O'Reilly

INTRODUCTION

During the past field season investigations of mineral deposits associated with the South Mountain Batholith concentrated on a linear trend of Sn, W and base metal deposits along the East Kemptville Shear Zone (EKSZ) (Fig. 1). Kontak (1987) first recognized the importance of localized, northeast-trending shear and mylonite zones within the East Kemptville tin deposit and its host leucogranite in southwest Nova Scotia. Smith (1985) documented a zone of intense shearing and mylonitization along the south contact of the Davis Lake Pluton and named the structure the Rushmere Lake Shear Zone (RLSZ) (Fig. 1). Examination of endo- and exocontact deposits of tin and related elements along the northern contact of the Davis Lake Pluton has shown that they are structurally controlled and associated, spatially at least, with northeast-trending shear zones. On this basis, the East Kemptville Shear Zone is defined as a series of continuous and(or) parallel northeast-trending structural breaks along which faulting and ductile shearing have occurred. To date, the EKSZ can be traced from within the South Mountain Batholith at Rocky Shore Lake southwest into Meguma Group metasedimentary rocks at Carleton, a distance of approximately 30 km (Fig. 1). There is limited evidence to suggest that the EKSZ may extend through the Wedgeport Pluton to the Atlantic coast south of Yarmouth.

SUMMARY OF FIELDWORK

FANNING LAKE CU, PB, ZN, AG, AU PROSPECT

Acadia Mineral Ventures recently completed a 13 hole diamond-drill program at the Fanning Lake Cu, Pb, Zn, Ag, Au prospect north of Carleton, Yarmouth County (Fig. 1). Gold mineralization associated with base metal sulphides at the Fanning Lake prospect has been known for many years but the potential has never been properly evaluated. The drilling program was designed to search for extensions of the previously recognized mineralized zones, test several new gold and base metal geochemical anomalies and test northeast-trending VLF conductors.

The prospect is hosted by fine- to medium-grained, light grey-green wacke, slate and argillite overprinted by zones of sericitization, silicification and carbonitization and often associated with quartz-calcite veinlets. Most sulphide mineralization (pyrite, arsenopyrite, chalcopyrite, galena and sphalerite) is associated with zones of intense silicification. In turn, zones of highest abundance of sulphide have returned the highest Ag and Au values.

A zone of pervasive, fracture-controlled hematization and kaolinization overprints the sericitization, silicification and carbonitization. This late alteration

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[1] Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

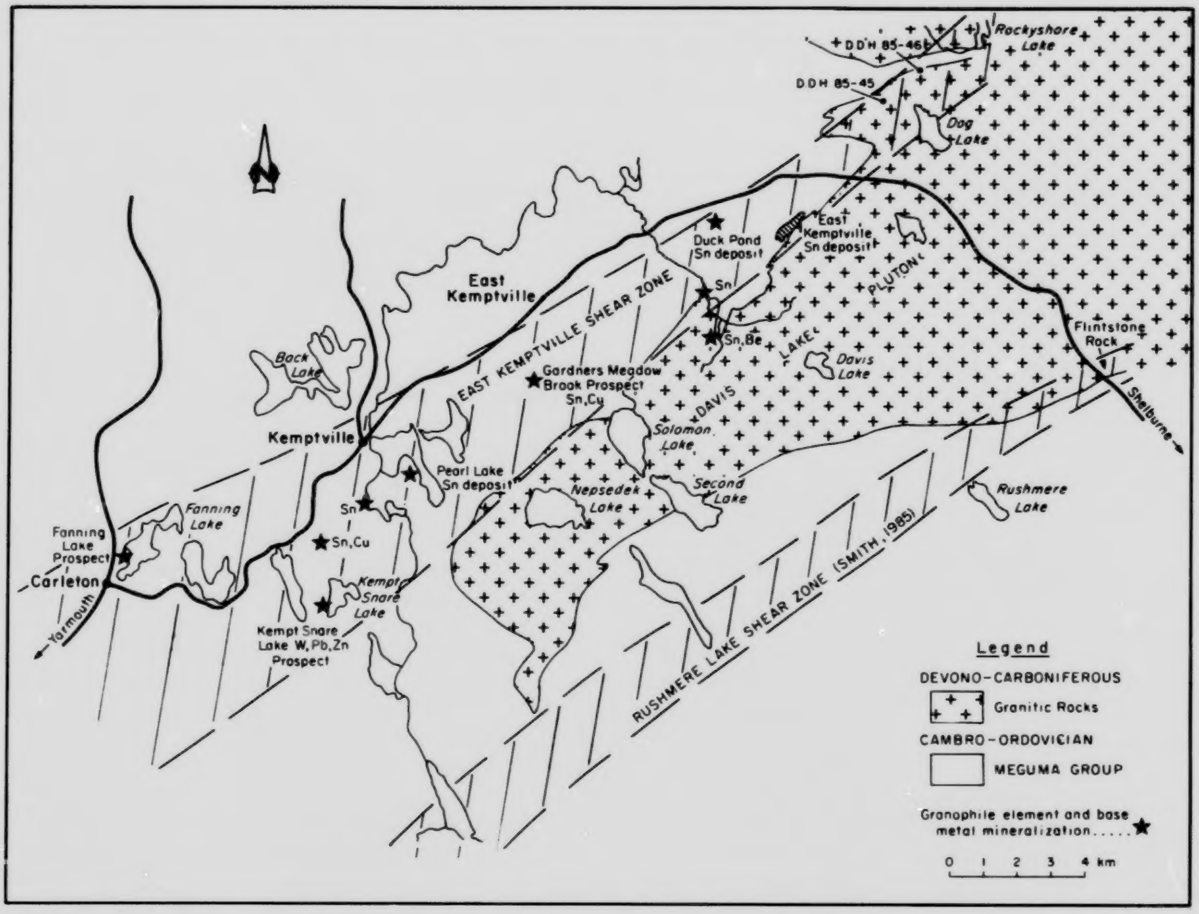
Rockyshore Lake
DDH 85-46
DDH 85-45
Dog Lake
East Kemptville Sn deposit
Duck Pond Sn deposit
Sn
Sn,Be
PLUTON
LAKE
DAVIS
Davis Lake
Flintstone Rock
Shelburne
East Kemptville
EAST KEMPTVILLE SHEAR ZONE
Back Lake
Gardners Meadow Brook Prospect Sn,Cu
Kemptville
Solomon Lake
Second Lake
Pearl Lake Sn deposit
Nepsedek Lake
Rushmere Lake
Fanning Lake
Fanning Lake Prospect
Carleton
Yarmouth
Sn
Sn,Cu
Kempt Snare Lake
Kempt Snare Lake W,Pb,Zn Prospect
RUSHMERE LAKE SHEAR ZONE (SMITH, 1985)
Legend
DEVONO-CARBONIFEROUS
Granitic Rocks
CAMBRO-ORDOVICIAN
MEGUMA GROUP
Granophile element and base metal mineralization.....
0 1 2 3 4 km

Figure 1. Generalized geology of the Davis Lake Pluton (SMB) showing locations of the East Kemptville and Rushmere Lake shear zones and granophile and base metal mineral deposits.

is best developed along northeast-trending, thick (>70 m) breccia zones. The altered breccia zones are interpreted to represent Fe and K metasomatism along faults related to movement along the EKSZ.

DUCK POND TIN DEPOSIT

The Duck Pond tin deposit occurs within Meguma Group metasedimentary rocks about 1 km northwest of the East Kemptville tin deposit (Fig. 1). Fifteen diamond-drill holes by Shell Canada Resources and Rio Algom Corporation have defined 3 parallel zones of low grade tin mineralization totalling 5.1 million tonnes of 0.129% Sn. Part of the deposit was uncovered during construction of the west dam of the tailings retention complex for the East Kemptville mine, thus providing an opportunity to examine and sample the surface extension of mineralized zones recognized in drilling. The project has been undertaken as a Bachelor's thesis by K. J. Hattie of Mount Allison University.

The Duck Pond tin deposit consists of an interbedded sequence of predominantly light green-grey slate and lesser amounts of wacke and siliceous layers. The highest tin values occur associated with a distinctive dark green chlorite-garnet alteration confined to siliceous interbeds. The occurrence of this mineralization and alteration within these particular beds suggests that the beds were either (1) originally porous due to their sand content, thus being more receptive to hydrothermal fluids (Kohlsmith and Wilson, 1980) than the surrounding slate, or (2) chemically receptive horizons which preferentially reacted with the migrating fluids. Zones of silicification, sericitization and pyritization occur within the slate units but these apparently carry much less tin mineralization than the chloritic zones. The chloritization, sericitization and silicification are overprinted by widespread, pervasive hematization and kaolinization similar to that recognized at the Fanning Lake prospect. This late alteration is best developed along a zone of intense shearing which traverses the northern portion of the deposit in a northeast direction. The shearing is linked to movement along the EKSZ.

ROCKY SHORE LAKE MYLONITE

Rio Algom Corporation drilled holes in 1985 to intersect two strong VLF conductors northeast of the East Kemptville tin mine in the area of Dog and Rocky Shore lakes (Fig. 1). The drilling failed to locate significant mineralization but both drillholes passed through intensely deformed granitic rocks which likely mark the northeast extension of the EKSZ. Deformed rocks range from mylonite, blastomylonite and fluidized breccia and are identical to rocks documented by Smith (1985) within the northeast-trending RLSZ which occurs along the south contact of the Davis Lake Pluton (Fig. 1). Hydrothermal alteration along the EKSZ in the area of Rocky Shore Lake has resulted in zones of intense silicification, kaolinization and emplacement of a thick (>30 m) quartz-kaolin dyke(?). This intrusion resembles one emplaced at Flintstone Rock along the RLSZ (Smith, 1985). No mineralization of significance was noted in either of these intrusions but their presence indicates that significant hydrothermal activity occurred along these structural breaks well within the confines of the Davis Lake Pluton.

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SOUTH MOUNTAIN BATHOLITH PROJECT: A PROGRESS REPORT ON BEDROCK MAPPING[1]

M. A. MacDonald, M. C. Corey, L. J. Ham and R. J. Horne

INTRODUCTION

The South Mountain Batholith (SMB) is a post-tectonic, peraluminous, composite batholith of Devono-Carboniferous age (Clarke and Halliday, 1980; Reynolds et al., 1987) that outcrops over 8000 km^2 of southwestern Nova Scotia. It is one of the largest granitoid batholiths in the Appalachian Orogen and accordingly has been the subject of several petrological and geochemical studies during the past decade (see MacDonald et al. (1987) for summary). Prior to the present work, regional geological mapping within the SMB was of a reconnaissance nature. In light of recent discoveries of significant mineralization within the batholith (e.g. the East Kemptville tin mine and Millet Brook uranium prospect) this project was designed to evaluate the mineral potential of the SMB via detailed regional geological mapping.

During the 1988 field season geological mapping was completed for N. T. S. sheets 21A/03, 04, 05, 06, 11, 12 and 14, thus concluding the mapping of the SMB. The following report outlines the classification scheme for division of granitic rock types, briefly summarizes the nature and distribution of the resulting lithotypes, makes some general observations on the geology of the batholith, gives the location of all known mineral occurrences and discusses some of the factors controlling mineralization.

GENERAL GEOLOGY

Previous workers (Smith, 1974; McKenzie and Clarke, 1975) divided the SMB primarily on the basis of the relative proportions of quartz, alkali feldspar and plagioclase (e.g. granodiorite and monzogranite) and the relative absence of mafic minerals (e.g. leucogranite). The results of their work are presented in Figure 1. Parts of the batholith were further subdivided on the basis of texture, for example the New Ross area (McKenzie, 1974; Charest, 1976), the West Dalhousie area (McKenzie, 1974), portions of N. T. S. sheets 21A/12, 21A/14 and 21A/15 (Smitheringale, 1973) and more recently the area near East Kemptville (Richardson, 1988). However, the present study represents the first attempt to systematically map the entire batholith.

The classification scheme for subdivision of granitoid rocks into distinct mappable phases is based on texture (e.g. equigranular, porphyritic, megacrystic, seriate), grain size (fine- <0.1 cm, medium- 0.1-0.5 cm, coarse- >0.5 cm) and visual estimates of the modal percentages of biotite, muscovite, cordierite and feldspar megacrysts (mostly alkali feldspar with minor plagioclase). Modal percentages of quartz, alkali feldspar and plagioclase, established from point counting of stained slabs, were used to determine lithologic type according to the classification scheme of Streckeisen (1976).

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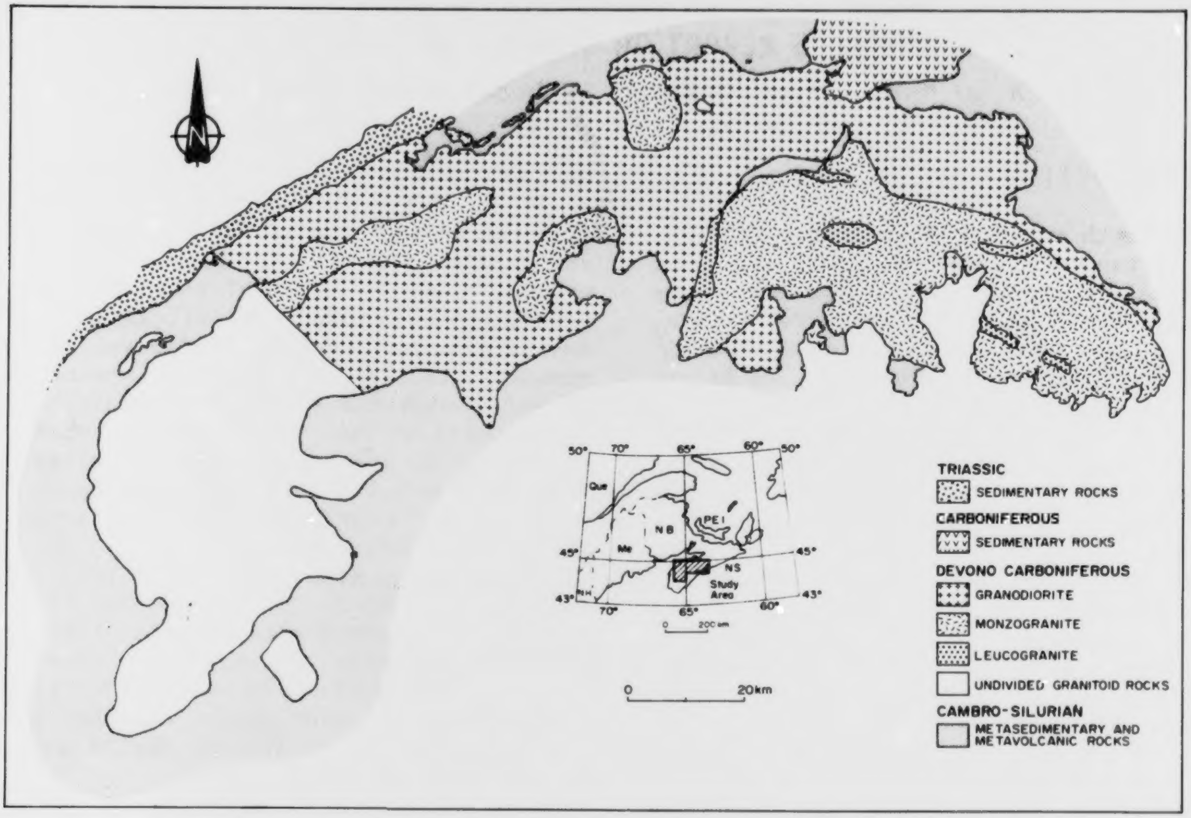
[1] Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement


N
50°
70°
65°
60°
50°
Que
NB
PEI
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45°
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NS
Study Area
43°
43°
70°
65°
60°
0 200 km
0 20km
TRIASSIC
SEDIMENTARY ROCKS
CARBONIFEROUS
SEDIMENTARY ROCKS
DEVONO CARBONIFEROUS
GRANODIORITE
MONZOGRANITE
LEUCOGRANITE
UNDIVIDED GRANITOID ROCKS
CAMBRO-SILURIAN
METASEDIMENTARY AND METAVOLCANIC ROCKS

Figure 1. Geological map of the South Mountain Batholith and surrounding rocks prior to the commencement of the current project. Granitic divisions are after Smith (1974) and McKenzie and Clarke (1975).

The above criteria allow subdivision of the SMB into eight rock types (Table 1), several of which are further subdivided on the basis of textural and mineralogical variations (subunits in Table 1). The distribution of these rock types in the SMB (excluding map sheet 21A/04) is displayed in Figure 2. The relative areal extent of each rock type and subunit was calculated by point counting a 1:150 000 scale geological map. Approximately 20,000 points were counted resulting in the following proportions: 9.6% granodiorite (8.0% megacrystic, 1.6% slightly megacrystic or equigranular); 52.2% biotite monzogranite (48.6% megacrystic, 3.4% slightly megacrystic and 0.2% porphyritic); 8.9% muscovite-biotite monzogranite (6.5% megacrystic, 1.5% equigranular and 0.9% cordierite-rich); 21.1% coarse grained leucomonzogranite (2.5% cordierite-rich); 6.8% fine- to medium-grained leucomonzogranite (5.3% fine- to medium-grained porphyritic or equigranular, 1.5% medium grained equigranular); 0.7% intrusive suites; 0.7% leucogranite; and 0.04% mafic porphyry. The granodiorite body east of Cloud Lake on map sheet 21A/15 contains minor amounts of 'tonalite' that may be due to albitic alteration of the granodiorite. The fine grained leucomonzogranite body situated at the granite/metasediment contact east of New Germany on map sheet 21A/10 is mostly syenogranitic, which probably

Table 1. Summary of lithological, textural and mineralogical information for the eight principal map units and eight subunits in Figure 2.

ROCK TYPE^{1}	SUBUNIT	LITHOLOGY^{3}	GRAIN SIZE^{4}	TEXTURE	COLOUR	MODAL MINERALOGY (% determined by point counting)					XENOLITHS
						BIOTITE	MUSCOVITE	CORDIERITE	GARNET	FELDSPAR MEGACRYSTS^{2}	
GRANODIORITE		granodiorite	m - c	megacrystic	lt - m grey	12 - 20	0 - tr	0 - tr	0 - tr	5 - 15	common to abundant
	S	granodiorite (tonalite)	f - c f - m	slightly megacrystic, seriate	lt - m grey	12 - 20 locally to 30%	0 - tr	0 - tr	0 - tr	0 - 2	common to abundant
BIOTITE MONZOGRANITE		monzogranite	m - c f - c	megacrystic	lt - m grey	10 - 15	0 - 1	0 - tr locally to 2%	0 - tr	10 - 15	common to abundant
	S	monzogranite (grandiorite)	f - c	slightly megacrystic, seriate	lt grey	12 - 14	tr	0 - tr	0 - tr	<2 - 5	common
	P	monzogranite	f - m	porphyritic	lt grey	10 - 15	0 - tr	0 - tr	0 - tr	0 - 1	rare
MUSCOVITE-BIOTITE MONZOGRANITE		monzogranite	m - c	megacrystic	lt grey	7 - 10	tr - 2	0 - tr	0 - tr	5 - 30	common
	E	monzogranite	f - m	equigranular, seriate, slightly megacrystic	lt grey -buff	7 - 10	tr - 2	0 - tr	0 - tr	0 - 5	common
	C	monzogranite	f - c	seriate, megacrystic	lt grey	5 - 8	tr - 2	1 - 4	0 - tr	5 - 20	rare
COARSE GRAINED LEUCOMONZOGRANITE		monzogranite	m - cg	megacrystic	lt grey to buff-orange	4 - 7	1 - 4	tr - 2	0 - tr	5 - 40	rare
	C	monzogranite	m - c	seriate-megacrystic	buff-orange	4 - 7	tr - 2	2 - 4	0 - tr	5 - 20	rare
FINE- TO MEDIUM-GRAINED LEUCOMONZOGRANITE		monzogranite (syenogranite)	f - m	texturally variable	lt grey to buff-orange	2 - 7	1 - 5	tr - 1	0 - tr	0 - 5	none
	P	monzogranite (syenogranite)	f - m	porphyritic	lt grey to buff-orange	2 - 7	1 - 5	tr - 1	0 - tr	0 - 5	none
	E	monzogranite (syenogranite)	f - m	equigranular to seriate	lt grey buff orange	tr - 5	1 - 4	tr - 2	0 - tr	0 - 2	none
INTRUSIVE SUITES		monzogranite (syenogranite)	f - c	equigranular-seriate, megacrystic	lt grey buff orange	2 - 10	tr - 4	tr - 2	tr - 4	0 - 2	none
LEUCOGRANITE		monzogranite (syenogranite)	f - m locally coarse	equigranular-seriate, porphyritic	lt grey to orange	tr - 2 locally 5%	2 - 10	tr - 2	0 - tr	0 - 1	none
MAFIC PORPHYRY		monzogranite (granodiorite)	f - m	porphyritic	grey-black	10 - 20	0 - tr	none	0 - tr	0 - 2	common to abundant

[1] Units arranged in decreasing mafic mineral content with the exception of mafic porphyry.
[2] Feldspar megacrysts are mostly alkali feldspar but may also be plagioclase.
[3] According to the fields of Streckeisen (1976).
[4] f - fine grained <0.1 cm m - medium grained 0.1 - 0.5 cm c - coarse grained 0.5 - 3.0 cm

reflects extensive K-feldspathization of a leucomonzogranite protolith (Kontak, personal communication).

Contacts between map units are both gradational and intrusive. Field relations for map sheets 11D/05, 11D/12, 11D/13, 21A/16(east), 21A/10, 21A/09, 21A/15 and 21A/16(west) are given in MacDonald and Horne (1987), Corey (1987), Ham and Horne (1987), Horne (1987), Corey (in press), MacDonald and Ham (in press) and Ham (in press), respectively.

The SMB is a composite granitoid body that comprises several discrete plutonic centres, each with its own unique crystallization history. For example the Halifax Pluton (HP) (MacDonald and Horne, 1988) contains a complex, zonal arrangement of map units. Systematic variations in the petrology and geochemistry of the HP are interpreted as resulting from processes within a single magma chamber in relative isolation from the remainder of the SMB. Similarly, the Big Indian Polyphase Intrusion (Kontak and Corey, 1988) is the only unit in the SMB to display the effects of pervasive garnet metasomatism. The coarse grained leucomonzogranite on map sheets 21A/03, 05 and 06 is the only unit that contains blue-grey alkali feldspar. These results corroborate Smith's (1979) postulation that the SMB is composite in nature and represents a series of coalesced magmas.

Geological mapping has also revealed that there are fundamental differences between the eastern and western halves of the batholith (ESMB and WSMB respectively). These include:

(1) The WSMB contains

significantly less leucomonzogranite and more biotite monzogranite than the ESMB.

(2) The coarse grained leucomonzogranite exposed on map sheets 21A/03, 05 and 06 (WSMB) does not contain smaller bodies of fine grained leucomonzogranitic and leucogranitic rocks and is therefore unlike any other unit of its type in the ESMB.

(3) There are significantly fewer map units in the WSMB than in the ESMB. It was first thought that this might be due only to the lack of bedrock control in the WSMB (i.e. the number of outcrops is inferior to that of the ESMB). However the combination of bedrock information, pebble clasts and boulder data in the overlying till (Finck and Graves, personal communication) supports the reduction in map units.

(4) The number of mineral occurrences diminishes toward the WSMB with only 10 occurrences on map sheets 21A/03, 05, 06, 11, 12 and 14 whereas there are 87 occurrences on map sheets 11D/05, 12, 13 and 21A/09, 10, 15 and 16. This may be partially due to poor bedrock exposure and thick till cover in most of the WSMB.

MINERALIZATION

The locations of all known mineral occurrences (with the exception of those on map sheet 21A/04) are given in Figure 2. Different symbols are used to denote the most significant commodity at each occurrence (e.g. U, Sn, W, Mo). Mineral showings are present within all rock types of the SMB. Mineralization occurs as disseminations, fracture fillings and in quartz-greisen veins, often accompanied by pervasive or fracture-related alteration, including hematization, kaolinization, muscovitization, chloritization, biotitization, albitization, K-feldspathization and tourmalinization. This intimate association indicates that a fluid phase attended mineralization and was perhaps critical for mineral deposition. These alteration phenomena are often repeated and superimposed.

The various types of mineralization (e.g. U, Sn) also reflect both regional and local zonation. For example, U showings dominate over most of map sheet 21A/15 whereas the area to the south of the metasediment inlier on map sheet 21A/16 contains polymetallic Sn, W and U deposits. This supports the metallogenic domains proposed by Chatterjee (1983). The explanation for these metallogenic zones is unclear, however they may reflect variable compositions in the source region for the granitic rocks or simply reflect mineral zonation coupled with differential erosional levels.

Mineral occurrences are more numerous near granite/metasediment and granite/granite contacts (Fig. 2) suggesting that contact zones may have acted as traps and(or) channelways for migrating fluids, as suggested by Charest (1976).

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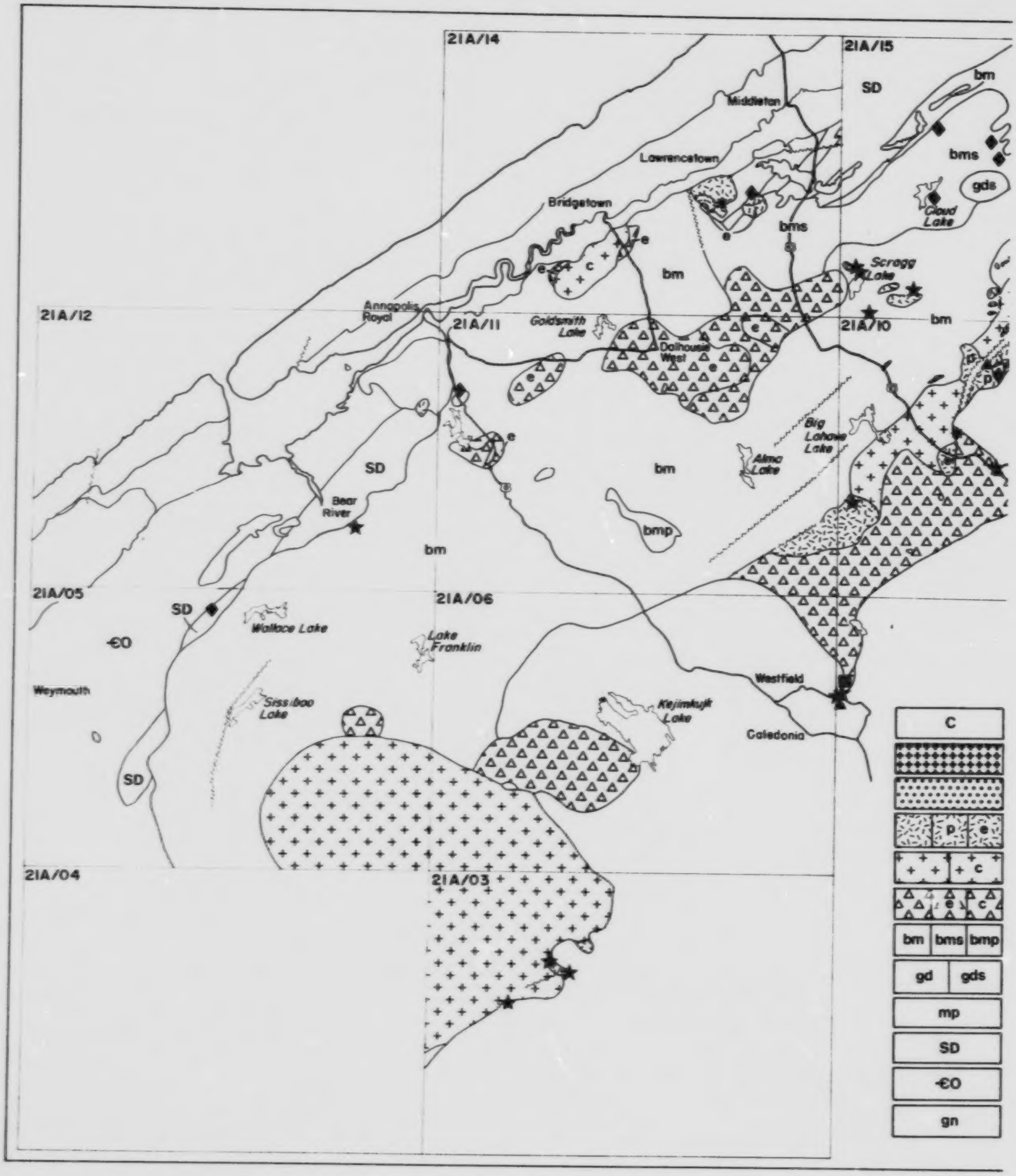
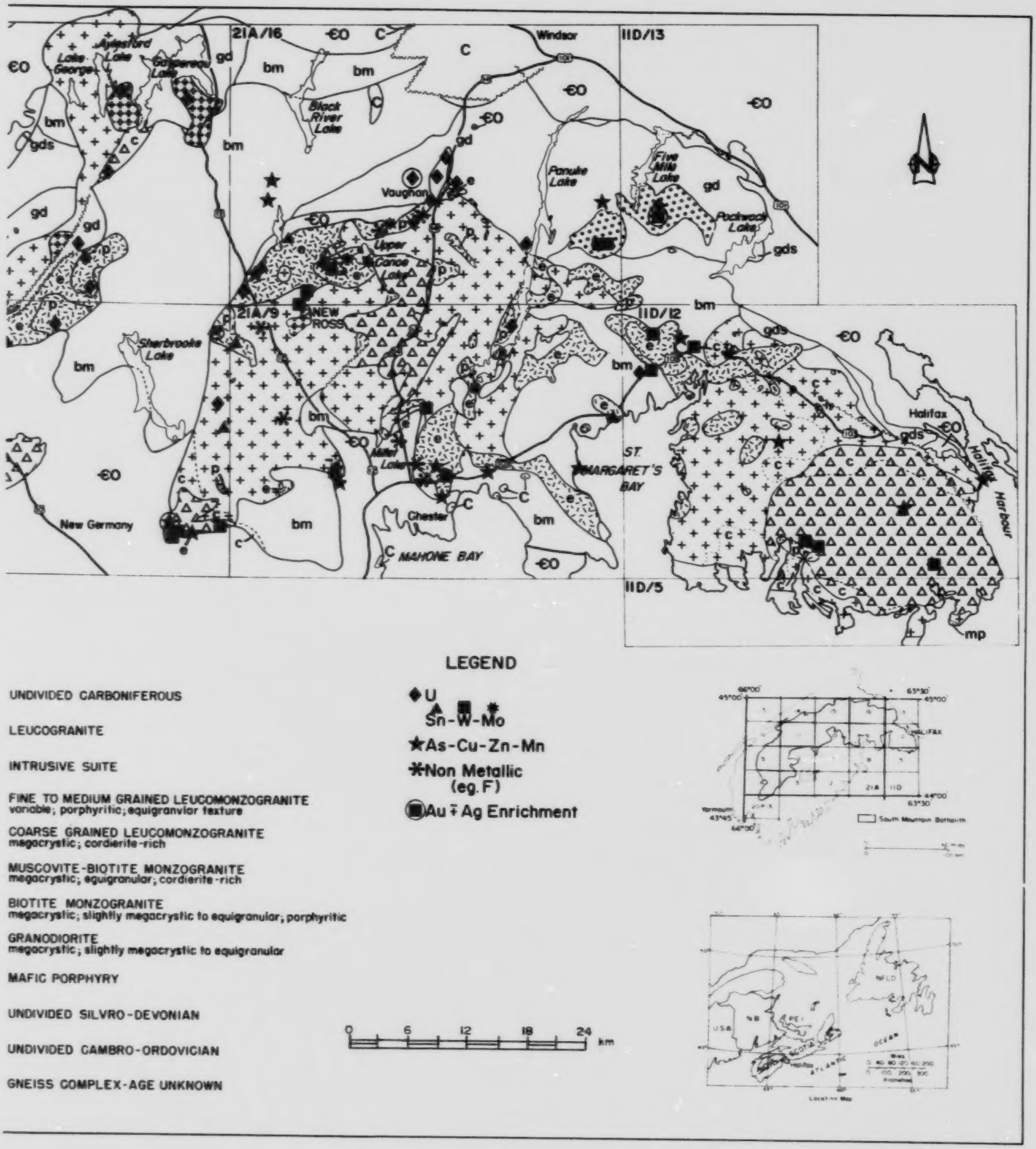

21A/14
21A/15
SD
bm
Middleton
Lawrencetown
bms
gds
Cloud Lake
Bridgetown
e
c
bms
bm
Scragg Lake
Annapolis Royal
21A/12
21A/11
Goldsmith Lake
Dalhousie West
21A/10
bm
p
SD
Bear River
bm
Big Lahave Lake
Alma Lake
bmp
21A/05
SD
21A/06
Wallace Lake
Lake Franklin
€O
Weymouth
Sissiboo Lake
Westfield
Kejimkujik Lake
Caledonia
SD
21A/04
21A/03
C
p
e
c
e
c
bm
bms
bmp
gd
gds
mp
SD
€O
gn

Figure 2. Geological map of the South Mountain Batholith and surrounding rocks (with the exception of 21A/04) outlining results of the current mapping program. A brief summary of each unit and subunit is given in Table 1. The locations of all known mineral occurrences in the batholith is given with various symbols corresponding to the most significant commodity at each occurrence.


21A/16
11D/13
21A/9
11D/12
11D/5
Windsor
Lake George
Aylesford Lake
Gaspereau Lake
Black River Lake
Panuke Lake
Five Mile Lake
Pockwock Lake
Vaughan
Upper Canoe Lake
NEW ROSS
Sherbrooke Lake
Mill Lake
Chester
MAHONE BAY
ST. MARGARET'S BAY
New Germany
Halifax
Halifax Harbour
€O
C
bm
gd
gds
p
e
c
mp
LEGEND
UNDIVIDED CARBONIFEROUS
LEUCOGRANITE
INTRUSIVE SUITE
FINE TO MEDIUM GRAINED LEUCOMONZOGRANITE
variable; porphyritic; equigranular texture
COARSE GRAINED LEUCOMONZOGRANITE
megacrystic; cordierite-rich
MUSCOVITE-BIOTITE MONZOGRANITE
megacrystic; equigranular; cordierite-rich
BIOTITE MONZOGRANITE
megacrystic; slightly megacrystic to equigranular; porphyritic
GRANODIORITE
megacrystic; slightly megacrystic to equigranular
MAFIC PORPHYRY
UNDIVIDED SILVRO-DEVONIAN
UNDIVIDED CAMBRO-ORDOVICIAN
GNEISS COMPLEX-AGE UNKNOWN
◆U
▲ ■ ✱ Sn-W-Mo
★As-Cu-Zn-Mn
✳Non Metallic (eg. F)
Au ∓ Ag Enrichment
0 6 12 18 24 km
64°00'
63°30'
45°00'
44°00'
43°45'
Yarmouth
HALIFAX
21A
11D
South Mountain Batholith
USA
NB
PEI
NFLD
NOVA SCOTIA
ATLANTIC OCEAN
Location Map

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THE SOUTH MOUNTAIN BATHOLITH PLEISTOCENE SURVEY: PROGRESS REPORT[1]

P. W. Finck, R. M. Graves and F. J. Boner

INTRODUCTION

A four year program of glacial mapping and till sampling commenced on the South Mountain Batholith (SMB) in 1985. Work on the SMB survey area was completed during the 1988 field season.

Areas covered by map sheets 11D/05, 11D/12, 11D/13 and the eastern half of 21A/09 were mapped and sampled during the 1985 field season (Fig. 1). In the 1986 field season map sheets 21A/10, 21A/15, 21A/16 and the western half of mapsheet 21A/09 were completed (Fig. 1). Field work was not conducted in 1987. This time was used to compile the data collected during the previous field seasons and to produce 1:50 000 scale glacial geology and geochemical maps for the 1985 and 1986 study areas. The remaining 40% of the SMB (approximately 3200 km^2), including portions of mapsheets 21A/03, 21A/04,

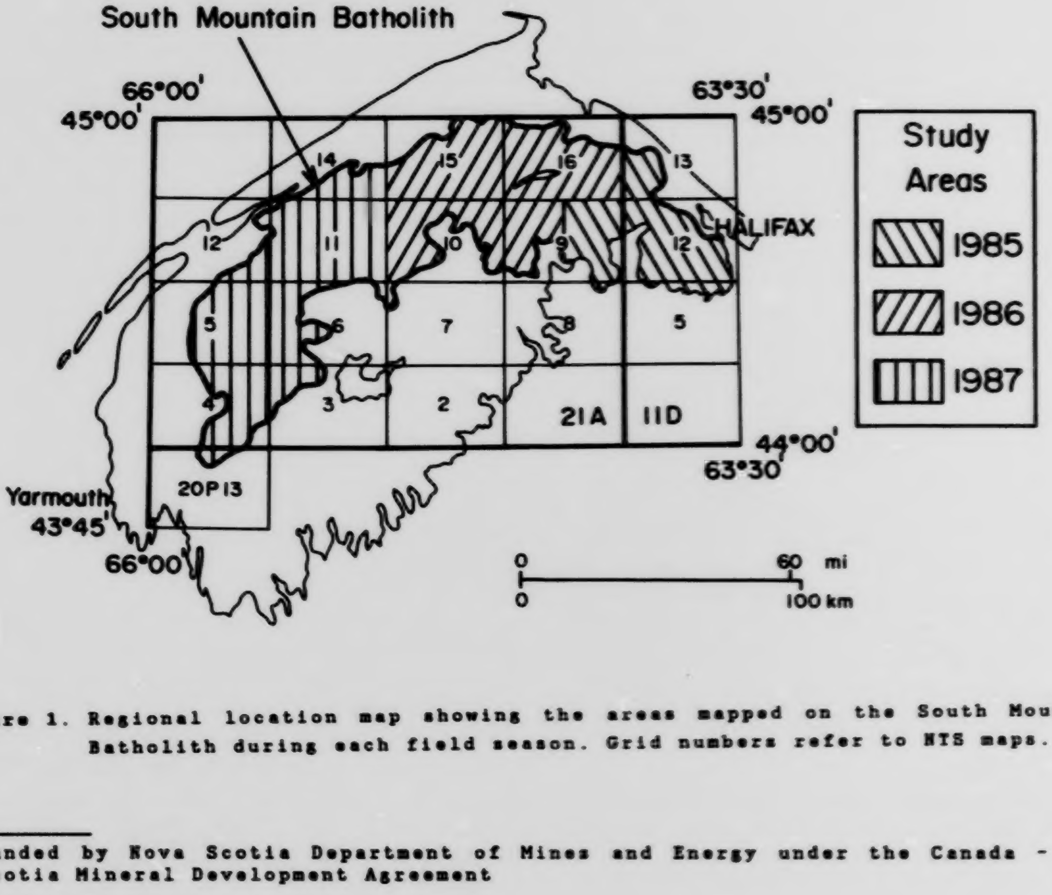
South Mountain Batholith
66°00'
45°00'
63°30'
45°00'
14
15
16
13
12
11
10
9
12
HALIFAX
5
6
7
8
5
4
3
2
21A
11D
44°00'
63°30'
20P13
Yarmouth
43°45'
66°00'
0
60 mi
0
100 km
Study Areas
1985
1986
1987

Figure 1. Regional location map showing the areas mapped on the South Mountain Batholith during each field season. Grid numbers refer to NTS maps.

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[1] Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

21A/05, 21A/06, 21A/07, 21A/11, 21A/12 and 21A/14, was mapped and sampled in 1988 (Fig. 1). Till and clast sampling was conducted on a 2 km^2 grid across the entire batholith. Approximately 2000 till samples were collected during the survey.

FIELD METHODS AND OBSERVATIONS

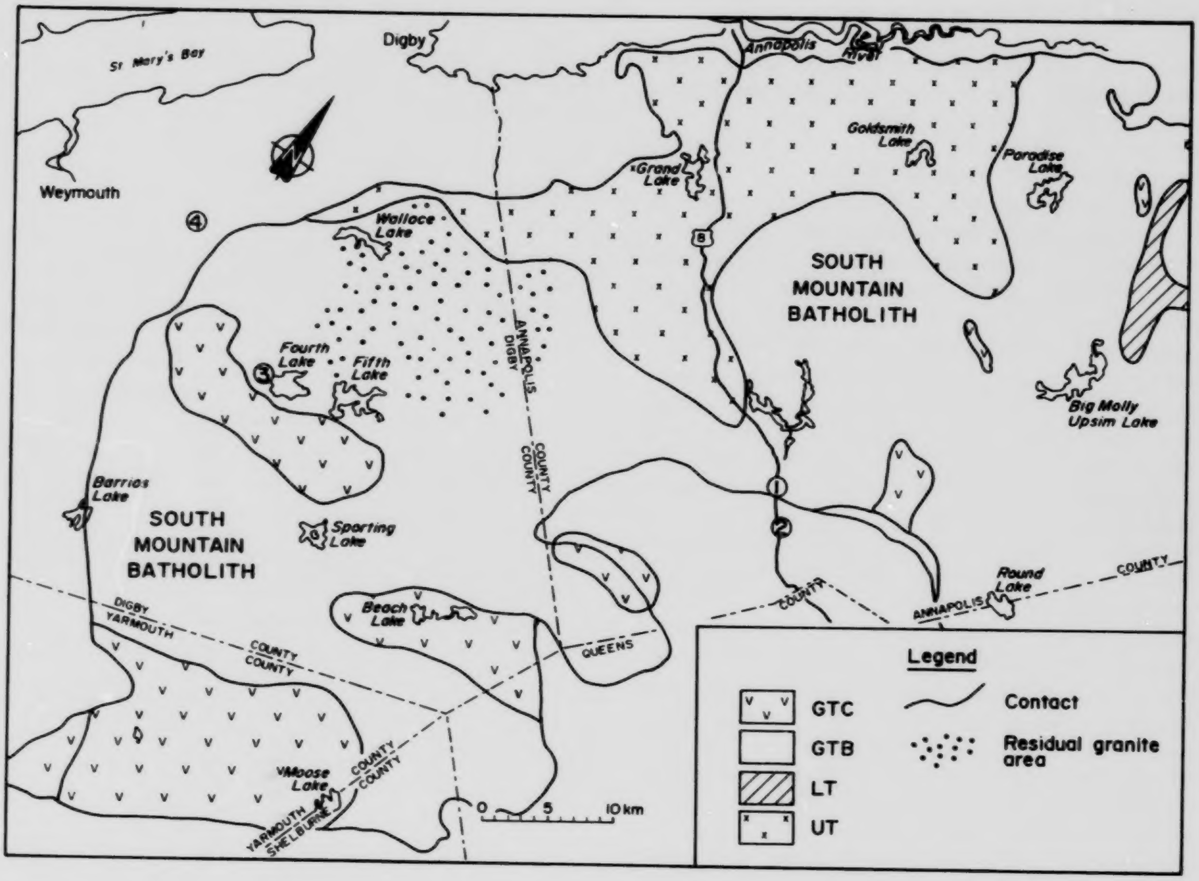
Glacial mapping primarily involved the examination of till cuts exposed along highways and bush roads and the inspection of coastal exposures. This work was augmented by a till and clast sampling survey using the available road coverage and by using helicopter support in remote areas.

Quaternary sediments were mapped and subdivided using the physical attributes of colour, texture, compaction, clast lithology, surface morphology and stratigraphic position. Four till units overlie the SMB (Graves and Finck, 1988). The oldest unit, Granite Till A (GTA), is a compact, moderate brown diamicton that is interpreted as a lodgment till and is normally only observed in drumlin cores. It was deposited during ice flow phase 1 of Stea and Finck (1984). The second oldest unit is the Lawrencetown Till (Grant, 1975; Stea and Fowler, 1979) which covers some upland areas of the SMB. It formed during ice flow phase 2, a regional southward flow, of Stea and Finck (1984). The Lawrencetown Till is reddish-brown and contains a significant proportion (40-80%) of non-granitic clasts transported from north of the SMB from the Cobequid Highlands, Carboniferous Basins, Meguma Group, North Mountain and Siluro-Ordivician volcanic and metasedimentary units.

The youngest units are bouldery, locally derived diamictons that cover much of the SMB. These are interpreted as tills and are called Granite Till B (GTB) and Granite Till C (GTC). Thick exposures of GTB and GTC are lacking on the SMB and the stratigraphic relationship between these tills is not easily observed. However, over Meguma Group bedrock south of the SMB, the lithologic facies equivalents (greywacke and slate tills) of GTB are overlain by granite-enriched till interpreted as GTC. This demonstrates the relative stratigraphic position of these tills. GTB is expressed as flat to undulating ground moraine and is characterized by renewal distances which range from tens to hundreds of metres. Renewal distance is a measure of clast uptake in a till and is defined as the distance needed for a bedrock lithology to achieve 50% of the clast content. GTC occurs as a hummocky moraine commonly associated with glaciofluvial deposits. The hummocks range in height from 3-15 m. The lithologic composition of GTC is more variable than GTB and represents incorporation of bedrock lithologies from a larger area. Renewal distances in GTC range from hundreds of metres to kilometres. These tills were formed during ice flow phases 3 and 4 (of Stea and Finck, 1984) and have dispersal directions indicating radiating ice flow off the SMB (ice flow phase 3) and dispersal from an ice cap external to the SMB (ice flow phase 4) in the Antigonish Highlands. Stea et al. (1988) speculate that ice flow phase 4 traversed the eastern portion of the SMB and formed ablation tills on mapsheets 21A/09 and 21A/15.

PRELIMINARY RESULTS OF 1988 FIELD MAPPING

Lawrencetown Till occurs on mapsheets 21A/06, 21A/11, 21A/12 and 21A/14 to the north and east of Kejimkujik National Park. West of the Park, Lawrencetown Till is absent and the SMB is overlain principally by GTB and GTC. In the northern and northwestern portion of the 1988 study area the deposits of granite tills and Lawrencetown Till are intermixed with remnants of pre-Pleistocene residual granite or saprolite. The saprolite reaches thicknesses of 3-4 m and is


St Mary's Bay
Digby
Weymouth
④
Annapolis River
Goldsmith Lake
Paradise Lake
Grand Lake
Wallace Lake
8
SOUTH MOUNTAIN BATHOLITH
Fourth Lake
③
Fifth Lake
ANNAPOLIS DIGBY
COUNTY COUNTY
Big Molly Upsim Lake
Barrios Lake
SOUTH MOUNTAIN BATHOLITH
Sporting Lake
①
②
Beach Lake
Round Lake
COUNTY
ANNAPOLIS
COUNTY
QUEENS
DIGBY YARMOUTH
COUNTY COUNTY
Moose Lake
COUNTY COUNTY
YARMOUTH SHELBURNE
0 5 10km
Legend
GTC
GTB
LT
UT
Contact
Residual granite area

Granite Till C: **GTC** ablation hummocks, rib moraine and glaciofluvial deposits interspersed with ground moraine.

Granite Till B: **GTB** ground moraine with isolated occurrences of granite residuum, Lawrencetown Till and glaciofluvial deposits.

Lawrencetown Till: **LT** red muddy till occurring as drumlins and ground moraine.

Undivided Tills: **UT** residuum, Lawrencetown Till, Granite Till B and glaciofluvial deposits.

Contact between the South Mountain Batholith and surrounding rocks (Meguma Group greywacke and slate, Torbrook Formation sedimentary rocks and Wolfville Formation sedimentary rocks).

Circled numbers refer to sites of geological interest referred to in text.

Note: Bedrock contact between the South Mountain Batholith and surrounding rocks after MacDonald et al. (this volume), Smith (1985) and unpublished data of Finck, Graves and Boner.

Figure 2. Preliminary glacial geology map for the 1988 study area.

seen underlying and incorporated into the granite tills and Lawrencetown Till.

Westward glacial flow associated with ice flow phase 3 is indicated by striation and clast dispersal evidence. Although diverse flow directions interpreted from moraine and landform structure, esker orientation, erratic dispersal and erosional evidence are evident in this till (Hickox, 1962; Grant, 1976; Finck et al., in press), the bulk of GTB and GTC has been transported in a southeastward direction. North of Kejimkujik National Park along Highway #8, a greywacke till derived from the Meguma Group to the south overlies granitic residuum (Fig. 2, site 1). This demonstrates northwestward transport of Meguma Group-derived till onto the SMB. The exposure is in the vicinity of the Meguma Group-SMB contact indicating that the transport distance of the greywacke till is a few hundred metres. Northwestward oriented (310°) crag and tail in this area (Fig. 2., site 2) relate to ice flow phase 3 of Stea and Finck (1984). This is the local direction of transport for some of the greywacke and granite tills of the area. West of Kejimkujik National Park, striations trending 290° inscribed on granite bedrock (Fig. 2, site 3) are overlain by granite till. Clasts and boulders of SMB provenance are observed in slate till and have been dispersed 3 km to the west of the SMB (Fig. 2, site 4). These observations of erosional and depositional evidence for glacial movement also relate to ice flow phase 3.

The bulk of granite till has been dispersed southeastward. South of the East Kemptville Mine, granite till hummocks occur 4 km south of a contact between the Davis Lake Pluton and the Meguma Group (Smith, 1985). This suggests either large scale dispersal of granitic debris southward across Meguma Group bedrock or that the granite-metasediment contact is not linear as presently defined, but is irregular. This question has yet to be resolved by the authors.

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CUMBERLAND BASIN PROJECT - ACTIVITIES AND PRODUCTS 1988[1]

R. C. Boehner, R. J. Ryan and D. C. Carter

Field mapping has been completed in the Cumberland Basin of Nova Scotia (Fig. 1) within the areas of map sheets 11E/11, 12, 13 and 14 and 21H/7, 8, 9, 10 and 16. A series of 93 field drafted geological maps at a scale of 1:10 000 is complete and will be released as Nova Scotia Department of Mines and Energy Open File Maps 88-39, 40, 41, 42 and 43. With further interpretation and final data integration, these maps will serve as the basis for compilation of the final colour maps that will accompany the Cumberland Basin Memoir. The 1:10 000 geological field maps include drillhole locations and descriptions, mineral occurrence/deposit locations, palynology sample locations and results, and outcrop distribution. Information on lithology and sedimentary structures is presented in graphic form and as annotated descriptions on the maps.

Previous project activity is summarized in Boehner et al. (1987), Rose and Carter (1987, 1988), Boehner (1988a, 1988b), Ryan, Calder and Boehner (1988) and Deal (1988). A synopsis of subsequent and current activities, primarily in a reference form, is presented below.

Drilling was undertaken in the Shubenacadie Basin (drillhole NSDME Alton 87-1) in order to obtain stratigraphic information. This drillhole was prematurely abandoned after intersecting a significant flow of natural gas, described by McMahon et al. (1988) and Carter (1988a, 1988b, and this volume).

As a follow-up to work on Windsor Group stratigraphy in the Cumberland Basin (Boehner, 1988a) drilling was initiated near Lower Maccan on the moderately dipping south limb of the Minudie Anticline. This drillhole (NSDME Lower Maccan 88-1) was abandoned at 434.3 m after indications of salt (pitting, veinlets, etc.) were observed in the redbeds beneath a section of interstratified marine carbonate, redbeds and anhydrite correlative with the main carbonate interval of the Windsor Group described by Boehner (1988a).

Carter is finalizing maps and a report on the geology of the Pugwash Salt Mine. Additional details on the petrography and geochemistry of the anhydrite units in the Pugwash Mine, described in Rose (1988) and Rose and Carter (1988), have confirmed the original megascopic interpretations of three distinct anhydrite members.

The role of evaporites in the structural development of Carboniferous Basins is outlined by Boehner and Carter (1988). In addition, several papers related to evaporite geology, including topics such as evaporite drilling methodology, borate minerals, and geophysical logging applications, are in preparation (Carter and Anderle, in prep.; Carter and Evans, in prep.; Carter, in prep.; and Carter and Bomback, in prep.). Carter et al. (1988) described the potential for biogenic sulphur deposits in Nova Scotia.

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[1] Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

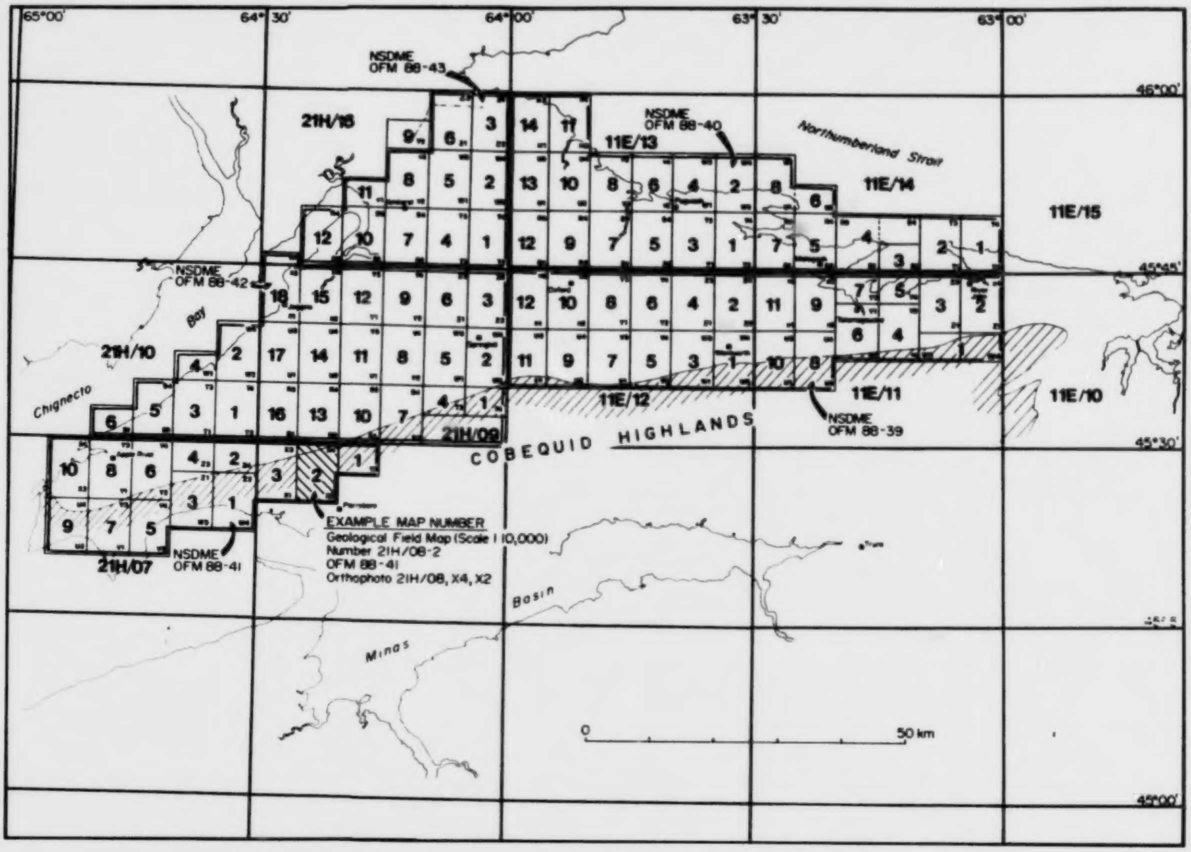
65°00'
64°30'
64°00'
63°30'
63°00'
46°00'
45°45'
45°30'
45°00'
NSDME OFM 88-43
NSDME OFM 88-40
NSDME OFM 88-42
NSDME OFM 88-39
NSDME OFM 88-41
21H/16
11E/13
11E/14
11E/15
21H/10
11E/12
11E/11
11E/10
21H/09
21H/07
Northumberland Strait
Bay
Chignecto
COBEQUID HIGHLANDS
Basin
Minas
EXAMPLE MAP NUMBER
Geological Field Map (Scale 1:10,000)
Number 21H/08-2
OFM 88-41
Orthophoto 21H/08, X4, X2
0
50 km

Figure 1. Cumberland Basin Project, NSDME Open File Map (OFM) Index map for the 1:10 000 geology field maps.

A summary of Carboniferous carbonate buildups in the Windsor and Horton Groups in Nova Scotia (Boehner, 1988b) is included in papers by Boehner and MacBeath (in press), Boehner, Giles, Murray and Ryan (in press), Boehner (in press), and Boehner, Horne and Ryan (in press).

Aspects of the economic geology, stratigraphy, structure, basin development and tectonic history of the Cumberland Basin are included in papers and presentations by Ryan et al. (1988), Ryan, Donohoe and Boehner (1988), Ryan, Turner, Stea and Rogers (1988), Ryan and Boehner (1988), Ryan and Van de Poll (1988), Calder et al. (1988) and Boehner et al. (1988).

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DRILLHOLE INFORMATION PRESENTATION: A LOGGER PROGRESS REPORT[1]

D. C. Carter, D. Rigby, D. Clarke and G. Davidson

INTRODUCTION

Large volumes of data, including engineering procedures and equipment, lithologic descriptions, mineral occurrences, stratigraphic interpretations, geochemical analyses and geophysical responses are generated by diamond-drilling operations. This database can be utilized most effectively if it is accessible, reproducible and manipulable. A drillhole logging, microcomputer software package provides a means whereby this data can be entered and stored, retrieved and displayed or printed in a number of formats at virtually any scale and, most importantly, be manipulated to compare and contrast the information with other similar data.

The Logger drillhole logging software package was purchased by the Mineral Resources Division in 1987 and is currently operated on a Compaq Portable II computer. The program offers versatility of presentation format through custom, user-designed plotting parameters. Two custom formats have been developed, one which displays lithologic and engineering information (Figs. 1, 2 and 3) and a second which displays lithologic, engineering and geophysical information (Fig. 4) . Both formats present lithologic information as graphic displays and as written descriptions and both are set up to accept and present geochemical analyses when available.

INPUT-OUTPUT

Data input is through the Program Editor (ASCII screen editor) and data may be entered in longhand or abbreviated form to a maximum of 255 characters per description but must follow the specific format of the software. The data file is compiled in the software package which contains translation algorithms, user-defined abbreviation tables, keyword association files and pattern files to convert the data into a graphic log. Output of the graphic log is directly from the software to the printer.

OBSERVATIONS

The drillhole plotting software has some limitations, particularly with regard to formatting written descriptions to the graphic log and the 255 character maximum. This problem is hopefully being corrected by the manufacturer. This limitation is outweighed by the versatility of the software in terms of variable set-up parameters for a variety of users and the variety of formats available for data presentation and manipulation.

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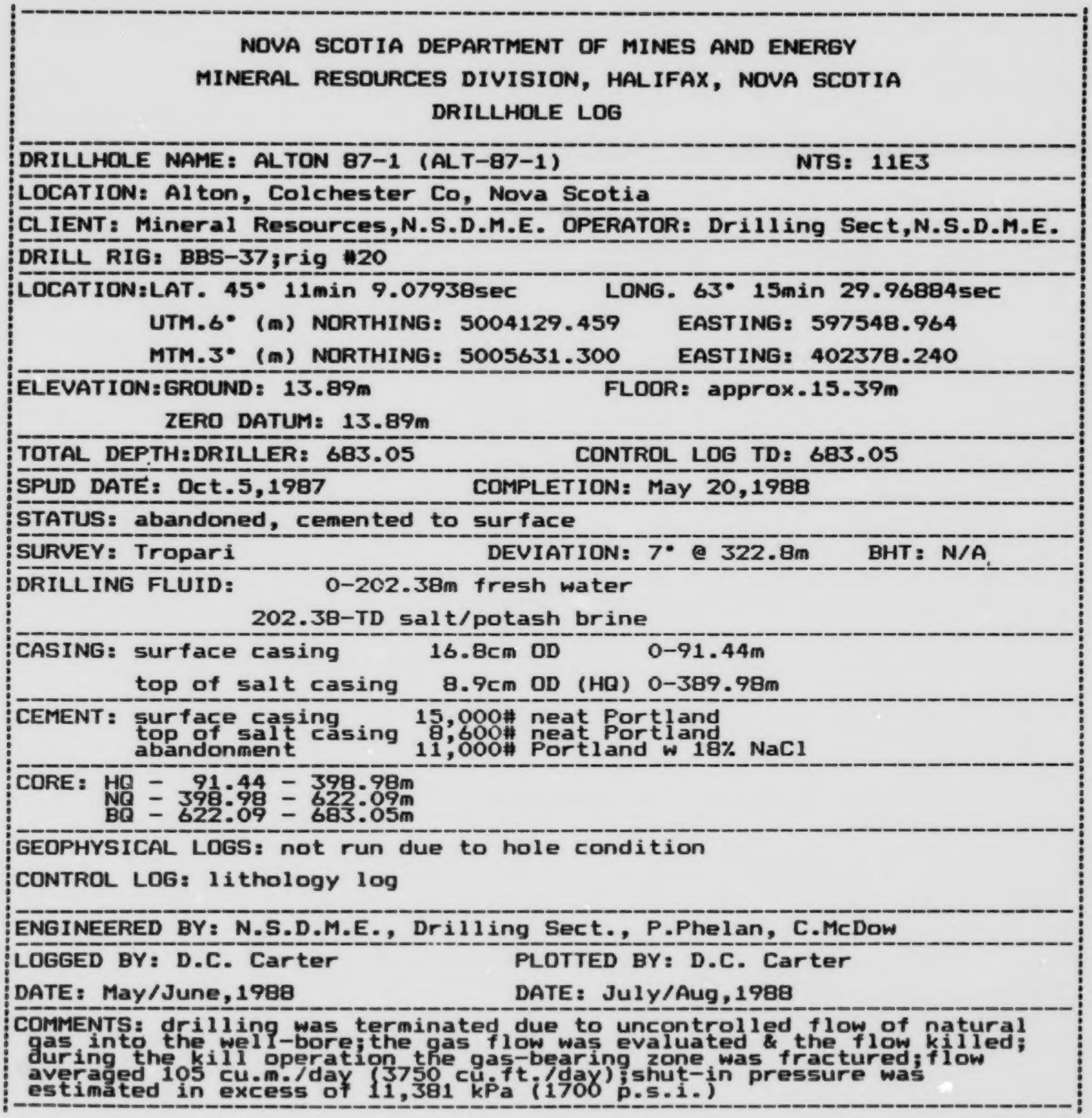
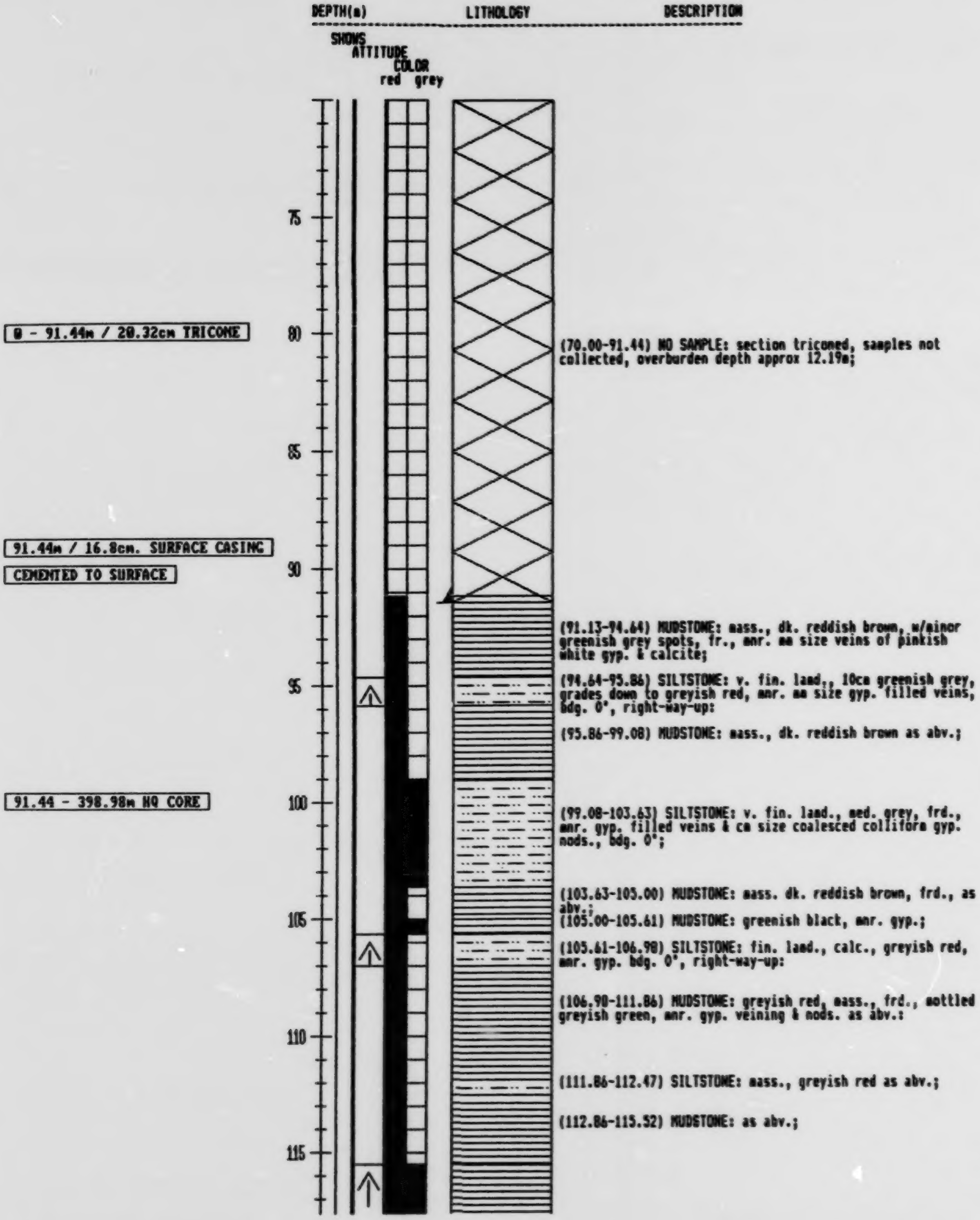
[1] Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement



```
                NOVA SCOTIA DEPARTMENT OF MINES AND ENERGY
             MINERAL RESOURCES DIVISION, HALIFAX, NOVA SCOTIA
                              DRILLHOLE LOG
DRILLHOLE NAME: ALTON 87-1 (ALT-87-1)                   NTS: 11E3
LOCATION: Alton, Colchester Co, Nova Scotia
CLIENT: Mineral Resources,N.S.D.M.E. OPERATOR: Drilling Sect,N.S.D.M.E.
DRILL RIG: BBS-37;rig #20
LOCATION:LAT. 45° 11min 9.07938sec      LONG. 63° 15min 29.96884sec
        UTM.6° (m) NORTHING: 5004129.459    EASTING: 597548.964
        MTM.3° (m) NORTHING: 5005631.300    EASTING: 402378.240
ELEVATION:GROUND: 13.89m                FLOOR: approx.15.39m
         ZERO DATUM: 13.89m
TOTAL DEPTH:DRILLER: 683.05           CONTROL LOG TD: 683.05
SPUD DATE: Oct.5,1987         COMPLETION: May 20,1988
STATUS: abandoned, cemented to surface
SURVEY: Tropari                DEVIATION: 7° @ 322.8m    BHT: N/A
DRILLING FLUID:       0-202.38m fresh water
             202.38-TD salt/potash brine
CASING: surface casing       16.8cm OD       0-91.44m
        top of salt casing   8.9cm OD (HQ) 0-389.98m
CEMENT: surface casing      15,000# neat Portland
        top of salt casing  8,600# neat Portland
        abandonment         11,000# Portland w 18% NaCl
CORE: HQ -  91.44 - 398.98m
      NQ - 398.98 - 622.09m
      BQ - 622.09 - 683.05m
GEOPHYSICAL LOGS: not run due to hole condition
CONTROL LOG: lithology log
ENGINEERED BY: N.S.D.M.E., Drilling Sect., P.Phelan, C.McDow
LOGGED BY: D.C. Carter            PLOTTED BY: D.C. Carter
DATE: May/June,1988               DATE: July/Aug,1988
COMMENTS: drilling was terminated due to uncontrolled flow of natural
 gas into the well-bore;the gas flow was evaluated & the flow killed;
 during the kill operation the gas-bearing zone was fractured;flow
 averaged 105 cu.m./day (3750 cu.ft./day);shut-in pressure was
 estimated in excess of 11,381 kPa (1700 p.s.i.)
```

Figure 1. Sample title page from the NSDME ALT-87-1 drillhole log. The title may be customized to a particular log format or user.


DEPTH(m)
LITHOLOGY
DESCRIPTION
SHOWS
ATTITUDE
COLOR
red
grey
75
80
85
90
95
100
105
110
115
0 - 91.44m / 20.32cm TRICONE
91.44m / 16.8cm. SURFACE CASING
CEMENTED TO SURFACE
91.44 - 398.98m HQ CORE

(70.00-91.44) NO SAMPLE: section triconed, samples not collected, overburden depth approx 12.19m;

(91.13-94.64) MUDSTONE: mass., dk. reddish brown, w/minor greenish grey spots, fr., mnr. mm size veins of pinkish white gyp. & calcite;

(94.64-95.86) SILTSTONE: v. fin. lamd., 10cm greenish grey, grades down to greyish red, mnr. mm size gyp. filled veins, bdg. 0°, right-way-up:

(95.86-99.08) MUDSTONE: mass., dk. reddish brown as abv.;

(99.08-103.63) SILTSTONE: v. fin. lamd., med. grey, frd., mnr. gyp. filled veins & cm size coalesced colliform gyp. nods., bdg. 0°;

(103.63-105.00) MUDSTONE: mass. dk. reddish brown, frd., as abv.;

(105.00-105.61) MUDSTONE: greenish black, mnr. gyp.;

(105.61-106.98) SILTSTONE: fin. lamd., calc., greyish red, mnr. gyp. bdg. 0°, right-way-up:

(106.98-111.86) MUDSTONE: greyish red, mass., frd., mottled greyish green, mnr. gyp. veining & nods. as abv.:

(111.86-112.47) SILTSTONE: mass., greyish red as abv.;

(112.86-115.52) MUDSTONE: as abv.;

Figure 2. Portion of the NSDME ALT-87-1 drillhole log displaying engineering information (hole size, casing size, position) relative to lithology. The left side of the log is open for columns displaying geochemical information. The stratigraphic attitude indicator is located from the keyword 'right-way-up' and the histogram color chart is plotted directly from a sub-file. Lithology symbols are located by the keywords 'MUDSTONE' and 'SILTSTONE'.

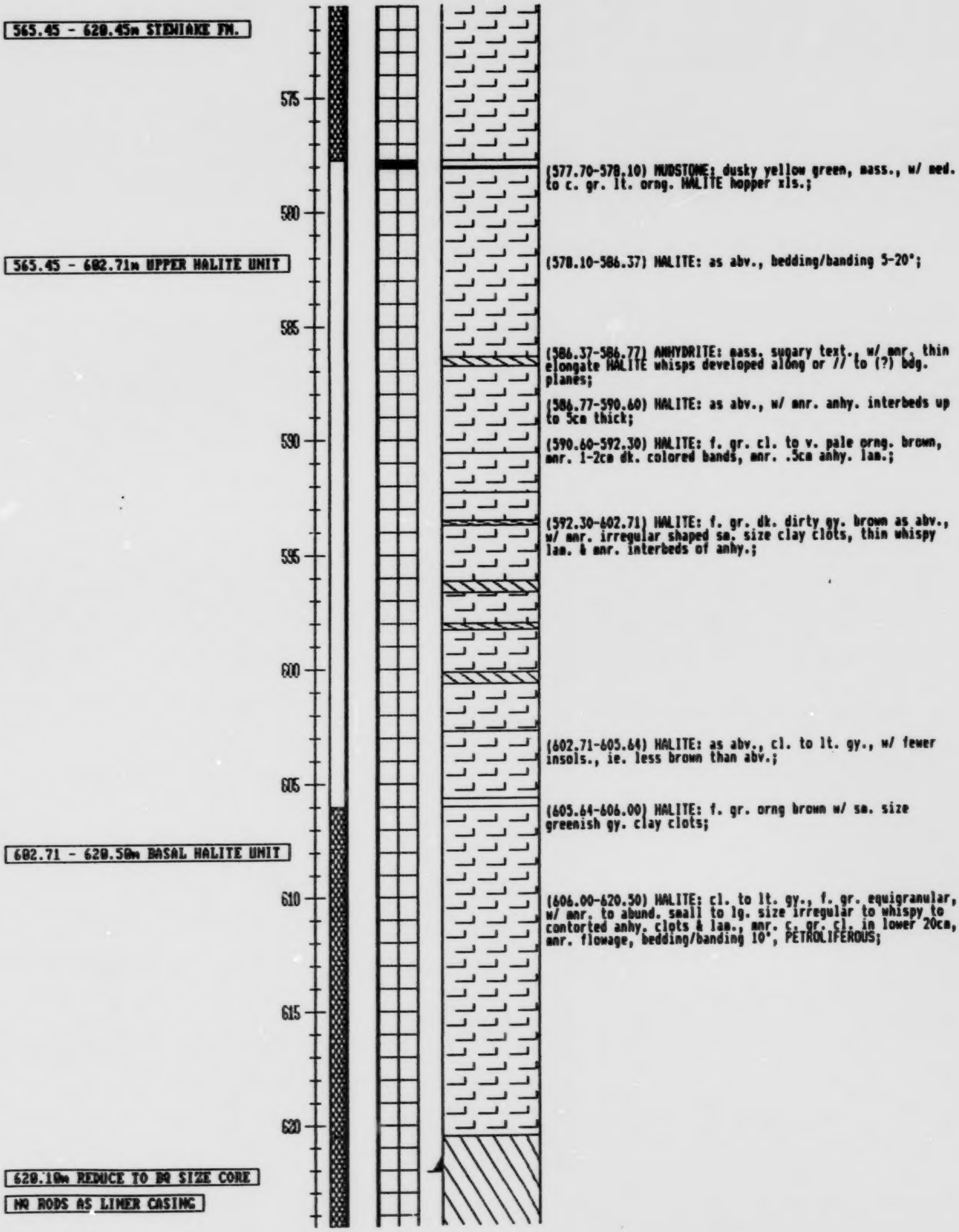

565.45 - 620.45m STEWIAKE FM.
565.45 - 602.71m UPPER HALITE UNIT
602.71 - 620.50m BASAL HALITE UNIT
620.10m REDUCE TO BQ SIZE CORE
NQ RODS AS LINER CASING
575
580
585
590
595
600
605
610
615
620
(577.70-578.10) MUDSTONE: dusky yellow green, mass., w/ med. to c. gr. lt. orng. HALITE hopper xls.;
(578.10-586.37) HALITE: as abv., bedding/banding 5-20°;
(586.37-586.77) ANHYDRITE: mass. sugary text., w/ mnr. thin elongate HALITE whisps developed along or // to (?) bdg. planes;
(586.77-590.60) HALITE: as abv., w/ mnr. anhy. interbeds up to 5cm thick;
(590.60-592.30) HALITE: f. gr. cl. to v. pale orng. brown, mnr. 1-2cm dk. colored bands, mnr. .5cm anhy. lam.;
(592.30-602.71) HALITE: f. gr. dk. dirty gy. brown as abv., w/ mnr. irregular shaped sm. size clay clots, thin whispy lam. & mnr. interbeds of anhy.;
(602.71-605.64) HALITE: as abv., cl. to lt. gy., w/ fewer insols., ie. less brown than abv.;
(605.64-606.00) HALITE: f. gr. orng brown w/ sm. size greenish gy. clay clots;
(606.00-620.50) HALITE: cl. to lt. gy., f. gr. equigranular, w/ mnr. to abund. small to lg. size irregular to whispy to contorted anhy. clots & lam., mnr. c. gr. cl. in lower 20cm, mnr. flowage, bedding/banding 10°, PETROLIFEROUS;

Figure 3. Portion of the NSDME ALT-87-1 drillhole log displaying engineering and stratigraphic information in a halite dominated sequence. Occurrence or show indicators are located by the keyword 'PETROLIFEROUS' in the description. Lithology symbols are located by the keywords 'MUDSTONE', 'HALITE' and 'ANHYDRITE'.

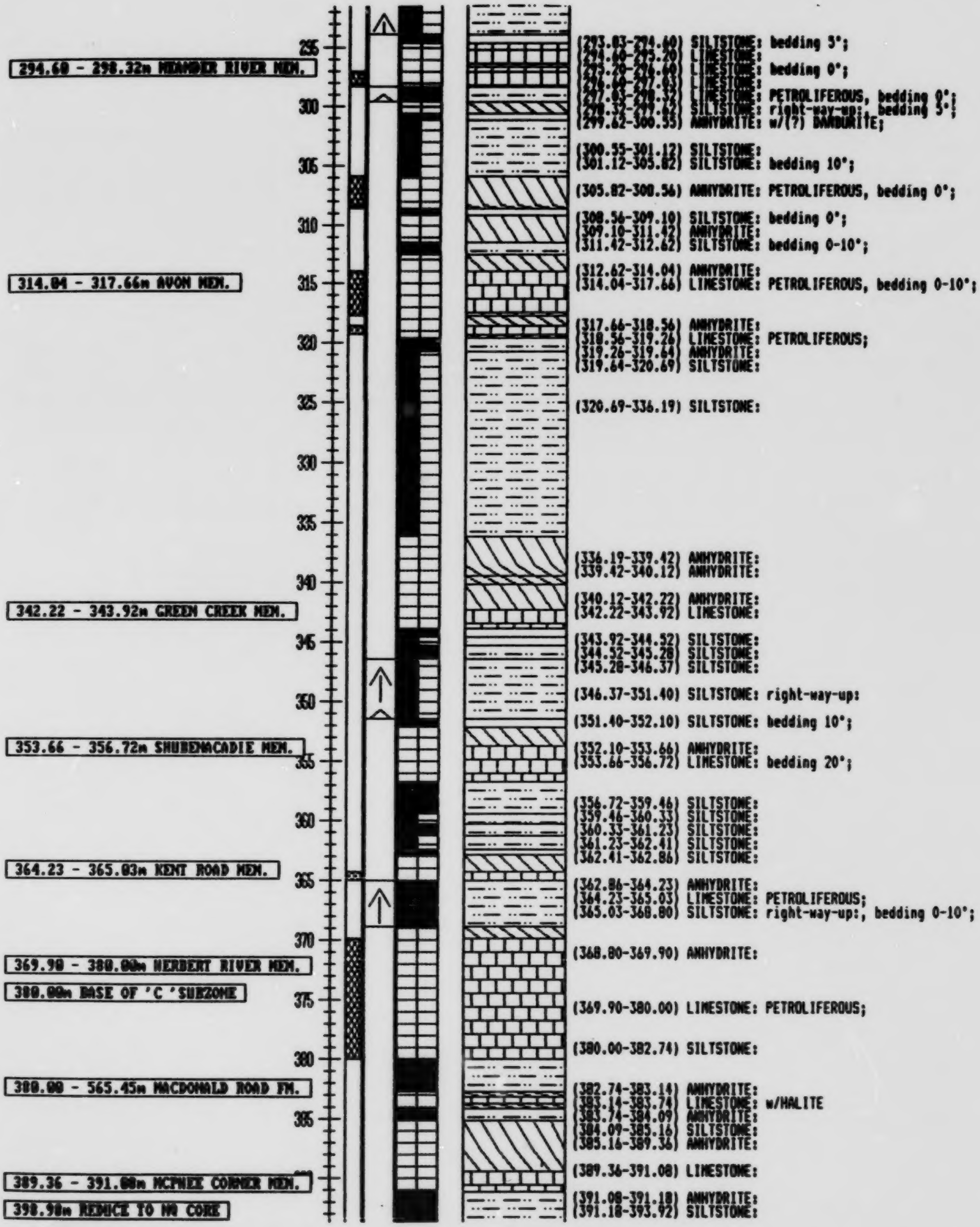

294.60 - 298.32m MEANDER RIVER MEM.
314.04 - 317.66m AVON MEM.
342.22 - 343.92m GREEN CREEK MEM.
353.66 - 356.72m SHUBENACADIE MEM.
364.23 - 365.03m KENT ROAD MEM.
369.90 - 380.00m HERBERT RIVER MEM.
380.00m BASE OF 'C 'SUBZONE
380.00 - 565.45m MACDONALD ROAD FM.
389.36 - 391.08m MCPHEE CORNER MEM.
390.90m REDUCE TO NQ CORE
295
300
305
310
315
320
325
330
335
340
345
350
355
360
365
370
375
380
385
(293.83-294.60) SILTSTONE: bedding 5°;
(294.60-295.20) LIMESTONE:
(295.20-296.60) LIMESTONE: bedding 0°;
(296.60-297.83) LIMESTONE:
(297.83-298.32) LIMESTONE: PETROLIFEROUS, bedding 0°;
(298.32-299.62) SILTSTONE: right-way-up:, bedding 5°;
(299.62-300.55) ANHYDRITE: w/(?) DANBURITE;
(300.55-301.12) SILTSTONE:
(301.12-305.82) SILTSTONE: bedding 10°;
(305.82-308.56) ANHYDRITE: PETROLIFEROUS, bedding 0°;
(308.56-309.10) SILTSTONE: bedding 0°;
(309.10-311.42) ANHYDRITE:
(311.42-312.62) SILTSTONE: bedding 0-10°;
(312.62-314.04) ANHYDRITE:
(314.04-317.66) LIMESTONE: PETROLIFEROUS, bedding 0-10°;
(317.66-318.56) ANHYDRITE:
(318.56-319.26) LIMESTONE: PETROLIFEROUS;
(319.26-319.64) ANHYDRITE:
(319.64-320.69) SILTSTONE:
(320.69-336.19) SILTSTONE:
(336.19-339.42) ANHYDRITE:
(339.42-340.12) ANHYDRITE:
(340.12-342.22) ANHYDRITE:
(342.22-343.92) LIMESTONE:
(343.92-344.52) SILTSTONE:
(344.52-345.28) SILTSTONE:
(345.28-346.37) SILTSTONE:
(346.37-351.40) SILTSTONE: right-way-up:
(351.40-352.10) SILTSTONE: bedding 10°;
(352.10-353.66) ANHYDRITE:
(353.66-356.72) LIMESTONE: bedding 20°;
(356.72-359.46) SILTSTONE:
(359.46-360.33) SILTSTONE:
(360.33-361.23) SILTSTONE:
(361.23-362.41) SILTSTONE:
(362.41-362.86) SILTSTONE:
(362.86-364.23) ANHYDRITE:
(364.23-365.03) LIMESTONE: PETROLIFEROUS;
(365.03-368.80) SILTSTONE: right-way-up:, bedding 0-10°;
(368.80-369.90) ANHYDRITE:
(369.90-380.00) LIMESTONE: PETROLIFEROUS;
(380.00-382.74) SILTSTONE:
(382.74-383.14) ANHYDRITE:
(383.14-383.74) LIMESTONE: w/HALITE
(383.74-384.09) ANHYDRITE:
(384.09-385.16) SILTSTONE:
(385.16-389.36) ANHYDRITE:
(389.36-391.08) LIMESTONE:
(391.08-391.18) ANHYDRITE:
(391.18-393.92) SILTSTONE:

Figure 4. Portion of the NSDME ALT-87-1 drillhole log. The reduced scale and descriptions highlight the stratigraphic information. Note the petroliferous shows and stratigraphic top indicators.

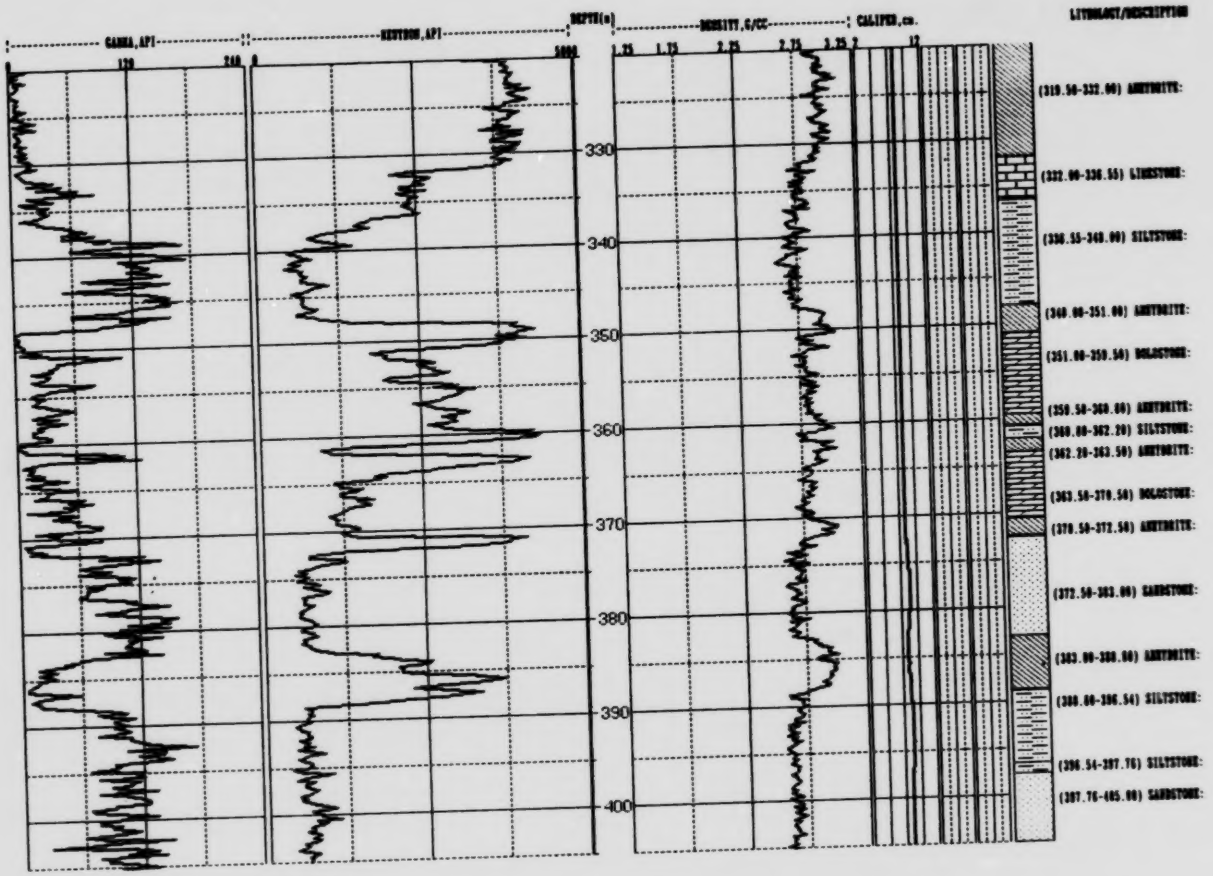


Figure 5. Portion of the NSDME LMA-88-1 drillhole log displaying geophysical responses and lithological information. Note that the two columns to the left of the lithology can accept geochemical information in either graphical or histogram form. Raw geophysical data has been smoothed for presentation.

STRATIGRAPHIC DRILLING IN THE SHUBENACADIE BASIN: A SUMMARY[1]

D. C. Carter

INTRODUCTION

A diamond drillhole was located near Alton (ALT-87-1) Colchester County (Fig. 1) to examine the stratigraphy and structure of the Windsor Group evaporite sequence in the north-central portion of the Shubenacadie Basin. The presence of a thick sequence of relatively undisturbed evaporites in the basin had been established by previous drilling (see the compilation work by Boehner, 1986 and references therein). There has been no indication of potash mineralization from within the evaporite sequence in this area. The drillhole was terminated at 683.05 m, in the Carrolls Corner Formation (basal anhydrite) of the Windsor Group, due to a significant and uncontrolled flow of natural gas into the well-bore.

DRILLING

Drilling operations were conducted at Alton by the Drilling Section, Mining Engineering Division of the Nova Scotia Department of Mines and Energy. The drillhole was spudded on October 5, 1987 and operations were completed on May 20, 1988. The hole was cemented to surface on abandonment. The hole was cored continuously from 91.44 m - 683.05 m and the core is stored at the NSDME core library in

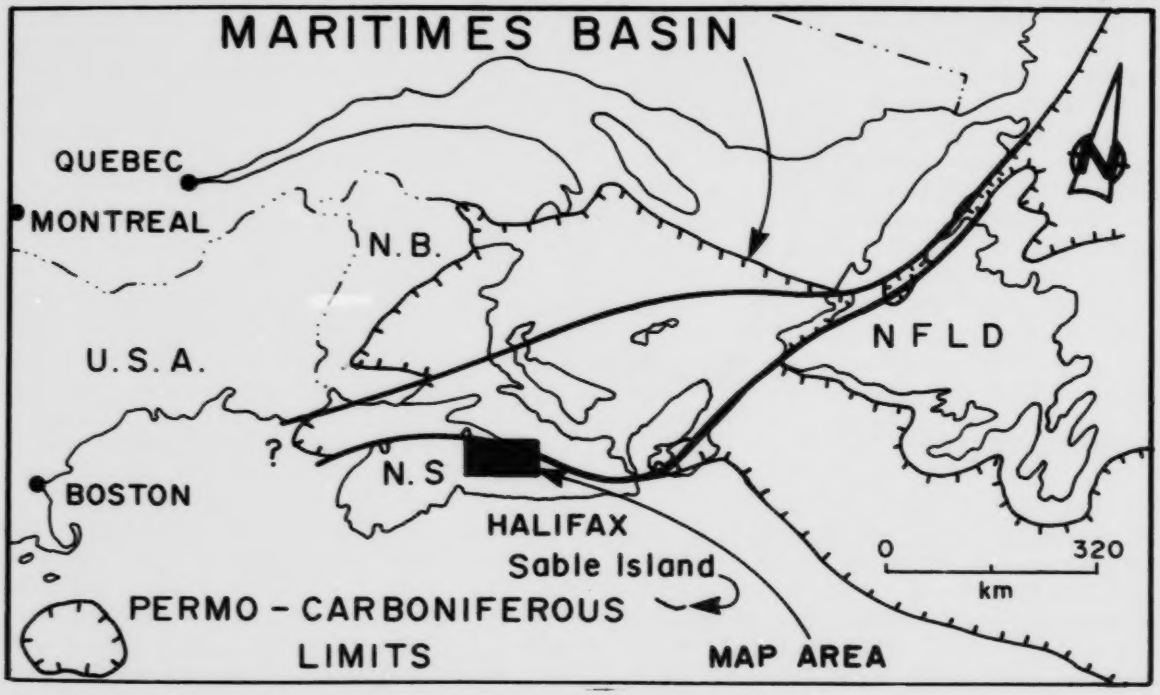


Figure 1. Regional location and geological setting.

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[1] Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

Stellarton. The reader is referred to the report by Carter (1988a) for a comprehensive discussion of the ALT-87-1 drillhole engineering.

GENERAL GEOLOGY

The Shubenacadie Basin (Fig. 2) is a northeast-trending, elongate, fault-bounded synclinal (graben) structure. Basin fill is dominantly early Carboniferous and variably deformed but is typically gently folded (except near faults). The basin is floored by folded metasediments of the Cambro-Ordovician Meguma Group upon which the Carboniferous basin fill was deposited with distinct angular unconformity. The basin fill comprises approximately 500 m of Tournaisian - early Viséan Horton Group nonmarine siliciclastics including red and grey sandstone, conglomerate and mudstone; 750 - 1000 m of middle-late Viséan Windsor Group marine evaporites, carbonates and redbed clastics; 100 m of late Viséan Canso Group transitional marine to nonmarine, grey to red mudstones and evaporites; and the fill is unconformably overlain by 100 m of Westphalian C Pictou Group nonmarine grey to red sandstones and mudstones. A detailed description of the geology of the Shubenacadie Basin area can be found in the compilation work by Boehner (1986) and references therein.

DRILLHOLE GEOLOGY

The ALT-87-1 drillhole was spudded by a sub-contracted water well drilling rig which triconed 91.44 m. No samples were taken over this interval. Overburden depth was approximately 12.19 m (Fig. 3). The Watering Brook Formation, Canso Group, from 91.44 - 238.50 m consists of dark reddish-brown and olive, greenish- and bluish-grey siltstone and mudstone with nodules and interbeds of anhydrite, some with halite-filled vugs. The section is oriented right way up, bedding is shallow (0-20°) and anhydrite becomes volumetrically dominant at the base of the unit which has a conformable basal contact.

The section from 238.50 - 683.05 m represents the Windsor Group. The Green Oaks Formation, from 238.50 - 380.00 m consists of olive-grey to black, marine, fossiliferous and petroliferous carbonates with greyish-red and greenish-grey siltstones and massive to nodular, bluish-grey, in part petroliferous, anhydrite. This unit is also right way up, has shallow bedding angles (0-20°) and has a conformable basal contact.

The MacDonald Road Formation, from 380.00 - 565.45 m, equivalent to the B subzone, consists of olive, grey and black fossiliferous and petroliferous carbonates with massive to laminated and nodular bluish-grey anhydrite, grey to brownish-grey and minor clear fine grained halite and minor reddish-brown and greenish-grey siltstone. The top of salt (base of dissolution) was encountered at 404.87 m. The section is right way up, bedding attitudes are shallow (0-10°) and the basal contact is conformable.

The Stewiacke Formation, from 565.45 - 620.45 m is equivalent to the upper portion of the A subzone. From 565.45 - 602.71 m is the upper halite unit which consists of clear, orange-brown and grey-brown, fine grained, banded dirty halite with minor interlaminae of yellow-green mudstone and massive, sucrosic anhydrite as interbeds and wispy clots. The halite is, in part, petroliferous, shallow dipping (5-20°) and grades conformably down to the basal halite unit at 602.71 - 620.50 m. The basal halite consists of clear to light grey, fine grained, equigranular halite with a lesser proportion of insoluble material (clay, silt and anhydrite) than the upper halite. Minor recrystallization is evident as are minor to abundant small- to large-size irregular clots and laminae of anhydrite. Bedding is

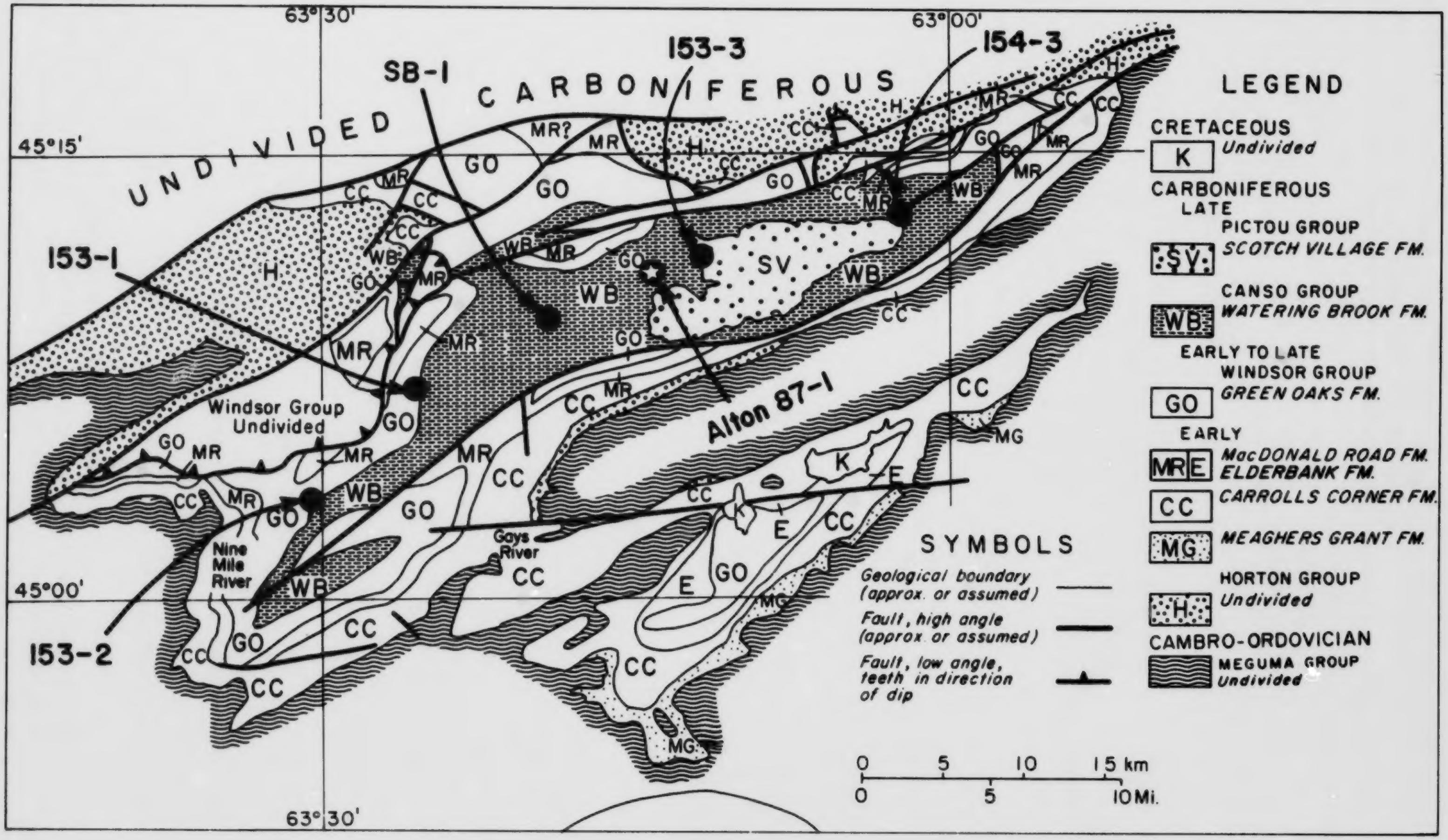
63°30'
63°00'
45°15'
45°00'
63°30'
UNDIVIDED CARBONIFEROUS
SB-1
153-1
153-2
153-3
154-3
Alton 87-1
Windsor Group Undivided
Nine Mile River
Gays River
H
GO
MR
MR?
CC
WB
SV
K
E
MG
LEGEND
CRETACEOUS
K Undivided
CARBONIFEROUS
LATE
PICTOU GROUP
SV SCOTCH VILLAGE FM.
CANSO GROUP
WB WATERING BROOK FM.
EARLY TO LATE
WINDSOR GROUP
GO GREEN OAKS FM.
EARLY
MR E MacDONALD ROAD FM. ELDERBANK FM.
CC CARROLLS CORNER FM.
MG MEAGHERS GRANT FM.
HORTON GROUP
H Undivided
CAMBRO-ORDOVICIAN
MEGUMA GROUP Undivided
SYMBOLS
Geological boundary (approx. or assumed)
Fault, high angle (approx. or assumed)
Fault, low angle, teeth in direction of dip
0 5 10 15 km
0 5 10 Mi.

Figure 2. Geological map of the Shubenacadie and Musquodoboit basins.

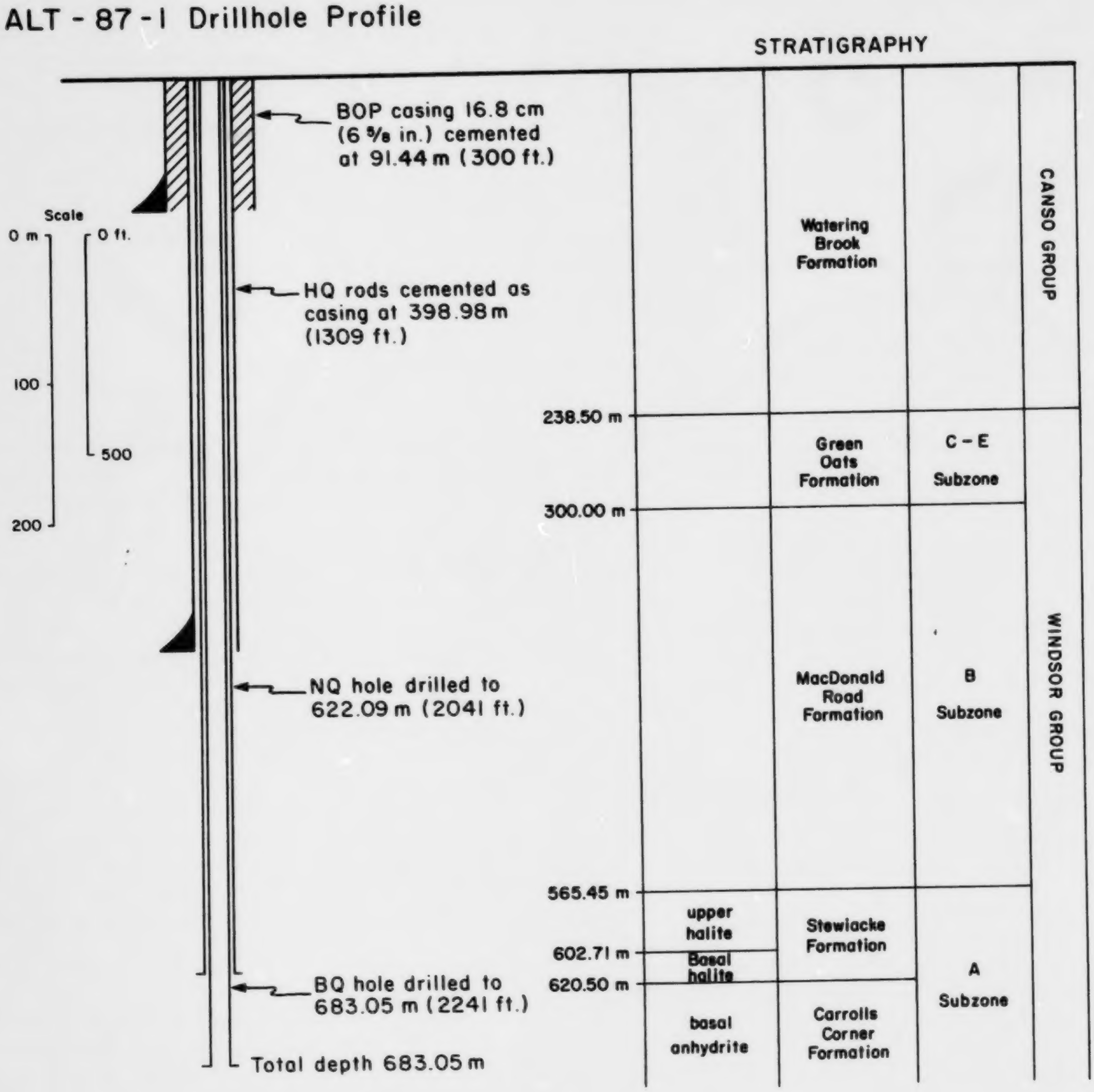
ALT - 87 - 1 Drillhole Profile
STRATIGRAPHY
BOP casing 16.8 cm (6 5/8 in.) cemented at 91.44 m (300 ft.)
Scale
0 m
100
200
0 ft.
500
HQ rods cemented as casing at 398.98 m (1309 ft.)
NQ hole drilled to 622.09 m (2041 ft.)
BQ hole drilled to 683.05 m (2241 ft.)
Total depth 683.05 m
238.50 m
300.00 m
565.45 m
602.71 m
620.50 m
Watering Brook Formation
CANSO GROUP
Green Oats Formation
C - E Subzone
MacDonald Road Formation
B Subzone
WINDSOR GROUP
upper halite
Basal halite
basal anhydrite
Stewiacke Formation
Carrolls Corner Formation
A Subzone

Figure 3. Stratigraphy of the Alton drillhole (not to scale).

shallow (10°) and the basal contact is conformable.

The Carrolls Corner Formation, from 620.50 - 683.05 m, is also part of the A subzone and consists of the basal anhydrite unit which, from 620.50 - 632.79 m, is transitional, bluish-grey, massive, sucrosic and includes minute- to small-size halite-filled vugs. This grades down to the more typical massive to laminated and nodular anhydrite with wispy laminae and inclusions of brown dolomitic silt and mud. The entire basal anhydrite section is petroliferous, particularly the upper transition zone. The base of the unit was not intersected. A detailed description of the geology of the Alton drillhole is in Carter (1988b).

Drilling was terminated due to the uncontrolled flow of natural gas into the well-bore. The gas was evaluated, given the limitations of the wireline coring equipment, and the average flow over six days was 3750 ft^3/day. Pressure was estimated to be in excess of 1500 psi. (Carter, 1988a; McMahon et al., 1988).

CONCLUSIONS

The drilling of the Alton (ALT-87-1) drillhole was successful in that it penetrated the basal anhydrite unit of the Windsor Group and has provided significant stratigraphic and structural information regarding that portion of the Shubenacadie Basin. It was unsuccessful, due to engineering difficulties and the gas kick, in reaching the desired stratigraphic depth (base of the Windsor Group) or the depth limitations of the equipment. The function, effectiveness and necessity of the blowout preventor equipment and casing (Carter, 1988a) was demonstrated and proven in the control and killing of the gas flow.

A significant hydrocarbon exploration target has been identified in the Alton area.

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1986: Salt and potash resources in Nova Scotia; Nova Scotia Department of Mines and Energy, Bulletin no. 5, 346 p.

Carter, D. C.
1988a: Report on the drilling of NSDME Alton 87-1; Nova Scotia Department of Mines and Energy, Open File Report 88-042, 13 p.

1988b: Geology of the NSDME Alton 87-1 drillhole; Nova Scotia Department of Mines and Energy, Open File Report 88-043.

McMahon, P. G., Carter, D. C. and Boehner, R. C.
1988: A natural gas occurrence in drillhole NSDME Alton 87-1; Nova Scotia Department of Mines and Energy, Open File Report 88-044, 17 p.

INVESTIGATION OF METALLIC MINERAL OCCURRENCES, METALLOTECTONIC PROJECT[1]

K. E. Northcote, G. Demont and A. Armitage[2]

INTRODUCTION

Examination of metallic mineral occurrences as part of the Metallotectonic Project includes literature research and field examination supported by chemical and petrographic analyses. A trial metallotectonic map of the Antigonish Highlands depicting mineral occurrences in their tectonic environment was prepared using recent mineral occurrence data from field examinations and existing unchecked data directly from Mineral Occurrence Data (MOD) cards. Subsequent field checks showed a significant percentage of the MOD files were inaccurate and incomplete. Some of these questioned data had been incorporated in the preliminary metallotectonic map and therefore, emphasis of fieldwork has been diverted from detailed study of selected mineral occurrences to routine examination of a larger number of occurrences for which MOD data are in question. These field checked data are being used for the Metallotectonic Project and for initial rebuilding of the MOD files.

PROCEDURE

In co-ordination with G. DeMont's research of literature, more than 100 metallic mineral occurrences have been field checked. Field checking has been concentrated in the Antigonish and Cobequid Highlands and the southern half of Cape Breton Island. Other selected occurrences have also been examined. To avoid unnecessary duplication of effort, the project has been co-ordinated with a similar project along the Minas Geofracture by Warren Ervine, under contract to the Geological Survey of Canada.

When an occurrence is located a concise description and(or) sketch of the location is provided for the MOD files. This should avoid repeated waste of time and effort by others looking for the same occurrence. The geological setting and form of the occurrence is described, mineralization, alteration and wallrock are sampled, and the occurrence is measured, mapped and photographed as required. Suggestions regarding economic or metallogenic significance may be made. Samples are analyzed for major and trace elements with representative fragments retained for petrographic and mineralographic analyses and reference. With the limitations of "Gold + 33" analyses in mind, samples were analyzed for at least 36 elements using a combination of direct irradiation/INAA, atomic absorption, x-ray fluorescence and conventional assays. Analyses for additional elements or greater precision are run as required depending upon results of petrographic and mineralographic studies. Vials of pulps are retained for possible future analyses. All of these data are entered in a database using Advanced Revelations software, published in

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[1] Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

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hardcopy open file, or offered as a selected data service.

RESULTS

Field examination of mineral occurrences has shown that an unknown but significant percentage of the MOD files cannot be used with confidence as a source of information for the Metallotectonic (or any other) Project. Some personal knowledge of the mineral occurrences, confidence in the data source or field checking is required.

At the time of preparation of this preliminary report petrographic and analytical data are lacking, but field checking has already "rediscovered" or reinforced the exploration potential of specific mineral occurrences and broader tectonic environments. One of the most obvious examples is found at Oban, north of St Peters on Cape Breton Island. A cluster of copper occurrences is present in an area of 1 km^2 in felsic Fourchu volcanics and the Sporting Mountain pluton. Although not confirmed, these occurrences may represent porphyry type mineralization in genetically related comagmatic, coeval volcanic and plutonic rocks. This possibility, coupled with the presence of gold-bearing quartz veins in the Sporting Mountain pluton, suggests that this tectonic environment is worthy of geological investigation and additional exploration. The significance of these occurrences is fairly widely known but is not apparent from MOD files.

The converse of the above example is also true. Review of past exploration programs, current regional geological studies, and examination and sampling of reported mineral occurrences may suggest lower than anticipated mineral potential. Absence as well as presence of favourable geological parameters should be included in MOD, if only by supplying references. This would avoid duplication of effort and assist in decisions of where and what kinds of exploration programs are required. The Boisdale Hills pluton (excluding the George River Group and the Coxheath pluton) provides such an example. Although bedrock exposure is poor and not all reported occurrences have been located and examined, there is an apparent paucity of porphyry type mineralization, veining, hydrothermal alteration and brecciation within the pluton. Barr and Setter (1986) have already suggested low mineral potential of the Boisdale Hills pluton based on field observations and lithogeochemistry.

Occasionally, unwarranted significance has been assigned to an occurrence and, unfortunately, cases of misrepresentation find their way into MOD files. Thorough field checks with analytical support will help resolve these problems.

CONCLUSIONS

The mineral occurrences field checked to date constitute a substantial number of the total mineral occurrences for which existing data are suspect. These, together with mineral occurrence data being compiled by other agencies and detailed studies of mineral occurrences by research geologists, will all contribute to a high quality Nova Scotia Metallic Mineral Occurrence Database.

REFERENCES

Barr, S. M. and Setter, J. R. D.
1986: Petrology of Granitoid Rocks of the Boisdale Peninsula, Central Cape Breton Island, Nova Scotia; Nova Scotia Department of Mines and Energy, Paper 84-1, 75 p.

GEOCHEMICAL ATLAS UPDATE: AN INVENTORY OF REGIONAL GEOCHEMICAL SURVEYS AND COMPILATION OF PRIVATE INDUSTRY GEOCHEMICAL ASSESSMENT REPORTS[1]

P. A. Lombard and P. J. Rogers

INTRODUCTION

Numerous geochemical surveys have been conducted within Nova Scotia by the Nova Scotia Department of Mines and Energy and private industry. These surveys range from large regional surveys to a few samples taken on a single claim block and analytical media include: soils, tills, stream sediments, stream waters, lake bottom sediments, lake waters and well water samples, all of which are analyzed for an array of elements.

Systematic cataloguing of geochemical surveys was conducted as part of the geochemical atlas project under the Canada - Nova Scotia Mineral Development Agreement. There are over 630 geochemical surveys conducted within the province in recent years on file. The initial collection of all pertinent geochemical assessment reports has been completed. All geochemical assessment reports and geochemical publications have been examined in the Nova Scotia Department of Mines and Energy library. From this study an inventory of four types of geochemical surveys was established: (1) NSDME regional geochemical surveys, (2) NSDME detailed geochemical surveys, (3) regional geochemical surveys conducted by private industry and (4) geochemical surveys by private industry listed under assessment reports. With an inventory of assessment reports pertaining to geochemical surveys, a better understanding of geochemical trends within the Province can be achieved.

ASSESSMENT REPORTS

The oldest pertinent geochemical assessment report included in the database dates back to 1965, and the most recent reports are from 1987. As the confidentiality on assessment report submissions expires on more recent geochemical surveys, they will be included in the inventory. A total of 610 assessment reports of surveys conducted within Nova Scotia by private industry have been summarized and the survey boundaries have been plotted on 1:50 000 scale base maps. Two series of maps were used to plot the assessment report boundaries since there was a change in the style of numbering assessment reports in 1986. Assessment reports with the new numbering system (since 1986) have been plotted on a separate base map series than those released prior to 1986.

The 610 geochemical assessment reports were summarized and stored using D-BaseIII software to produce a database. Future plans are to transfer the D-base III assessment files into the newly acquired Revelation 1A software. The 610 assessment reports in the database were summarized as shown in Table 1.

REGIONAL GEOCHEMICAL SURVEYS

The boundaries of regional geochemical

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[1] Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

Table 1. Fields in the assessment report database.

Fieldname	Explanation
NTS	Map co-ordinates and assessment report number.
Elements	Elements that were analyzed for in the survey.
Company	Company and year the report was published.
Survtype	Type of survey or sample medium and the number of samples taken (eg. soil (33) till (57)).
Gridsize	Distance between survey lines.
Spacing	Distance between samples.
Method	Method of sampling.
Laboratory	Laboratory that conducted the analysis of the samples in the survey.
Analysis	Method of analysis.
Acidextra	Type of acid extraction used in the analysis.
Remarks	Any additional information.

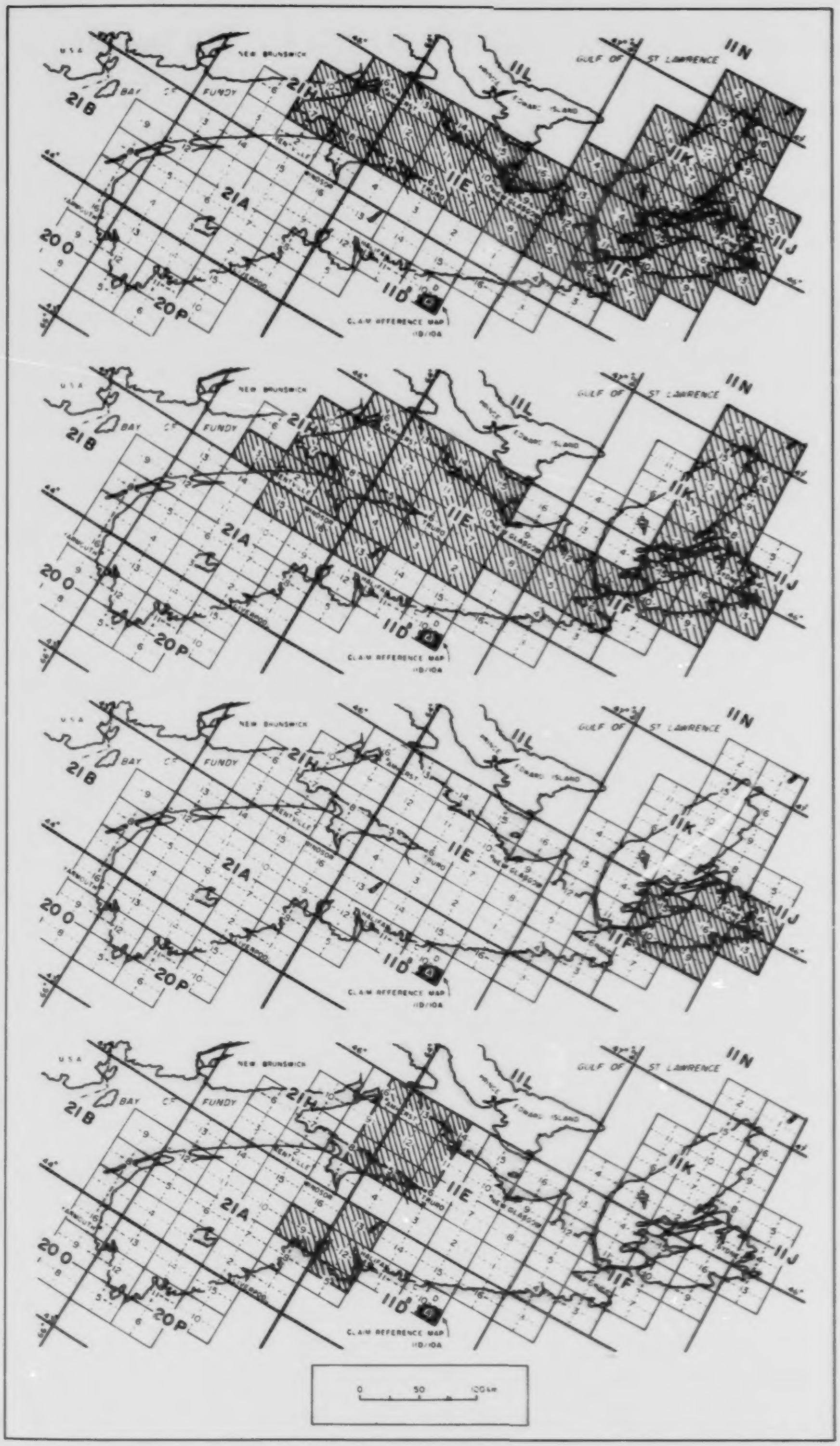
surveys conducted by NSDME and private industry within the province were plotted on a 1:625 000 scale base map for illustration purposes. A total of 10 regional surveys completed by private industry were plotted on a base map and summarized in the same manner as the assessment reports. Continuing research includes compiling the regional and local geochemical surveys conducted by NSDME (Fig. 1).

DATABASE SOFTWARE

A geochemical software computer package (Datamine\GX) was purchased in May, 1988 to produce a standard in-house geochemical database. The Datamine modules purchased by the Mineral Resources Division provide the flexibility to produce non-parametric and parametric summary statistics and geochemical anomaly plots based on population thresholds. The Datamine software has been used to establish a database for the following NSDME regional geochemical surveys: (1) 1977-78 Regional Lake Sediment Survey, (2) 1981 Regional Stream Sediment Re-analysis sites, (3) 1982-83 Regional Stream Sediment Survey and (4) 1983 Regional Lake Bottom Sediment Survey. Datamine will facilitate the more rapid production of geochemical reports and maps, and mineral responses can be better detected to illustrate regional geochemical trends within the Province.

REFERENCES

Graves, R. M., Finck, P. W. and Boner, F. J.
1987: Geochemistry of the granite till sheet overlying the eastern South Mountain Batholith; *in*


U.S.A.
NEW BRUNSWICK
BAY OF FUNDY
GULF OF ST LAWRENCE
PRINCE EDWARD ISLAND
21B
21H
21A
20O
20P
11D
11E
11F
11K
11J
11L
11N
YARMOUTH
KENTVILLE
WINDSOR
TRURO
NEW GLASGOW
HALIFAX
CLAIM REFERENCE MAP 11D/10A
0 50 100km

Precious metals-bulk stream sediment survey

n = 3073

(Lombard and Mills, 1987)

Stream sediment survey

n = 5324

(Rogers and MacDonald, 1984)

Lake bottom survey

n = 354

(Rogers and MacDonald, 1984)

Till geochemistry

n = 800

(Turner and Stea, 1987; Graves et al., 1987)

Figure 1. Boundaries of 4 recent regional geochemical surveys conducted by NSDME.

Mines and Minerals Branch, Report of Activities 1987, Part A, eds. J. L. Bates and D. R. MacDonald; Nova Scotia Department of Mines and Energy, Report 87-5, p. 129-135.

Lombard, P. A. and Mills, R. F.
1987: Regional geochemical surveys; *in* Mines and Minerals Branch, Report of Activities 1987, Part A, eds. J. L. Bates and D. R. MacDonald; Nova Scotia Department of Mines and Energy, Report 87-5, p. 147-149.

Rogers, P. J. and MacDonald, M. A.
1985: Regional geochemical surveys; *in* Mines and Minerals Branch, Report of Activities 1984, eds. K. A. Mills and J. L. Bates; Nova Scotia Department of Mines and Energy, Report 85-1, p. 55-68.

Turner, R. G. and Stea, R. R.
1987: Regional till geochemical trends in northern Nova Scotia; *in* Mines and Minerals Branch, Report of Activities 1987, Part A, eds. J. L. Bates and D. R. MacDonald; Nova Scotia Department of Mines and Energy, Report 87-5, p. 153-158.

EXPLORATION TARGET SELECTION: AN UPDATE ON STREAM SEDIMENT GEOCHEMISTRY AND CATCHMENT BASIN ANALYSIS FROM THE COBEQUID HIGHLANDS OF NOVA SCOTIA[1]

P. J. Rogers, G. F. Bonham-Carter[2] and D. J. Ellwood[2]

This is a preliminary progress report on a joint project between the Nova Scotia Department of Mines and Energy (NSDME) and Energy Mines and Resources, Geological Survey of Canada. The study area was selected on the basis of available detailed geological maps (Donohoe and Wallace, 1982). The study area is outlined in Figure 1a and NSDME Open File coverage is shown in Figure 1b. The results of the study will be published as a Geological Survey of Canada Report as a series of colour maps with accompanying text. Other published data on the project can be found in Bonham-Carter et al., 1987 and Rogers et al., 1986.

Regional and detailed geochemical exploration of the Cobequid Highlands has been carried out intermittently since 1960. In a 1983 regional geochemical survey about 1500 stream sediment and water samples at an average density of 1 sample per 2.5 km^2 were collected. The sediments were analyzed for Cu, Pb, Zn, Ag, Fe, Mn, Ni, Co, As, Hg, U and Mo, and the waters for U, F and pH (Rogers and MacDonald, 1984).

The Cobequid Highlands area serves as a case example of how catchment basin analysis (CBA) can be used to refine background characterization and aid in the interpretation of regional geochemical survey data. Each stream sediment sample defines its own catchment basin as a polygon which is taken as the zone of influence for the sample (Fig. 2). The polygon outline and geological maps were raster scanned to produce jointly registered images.

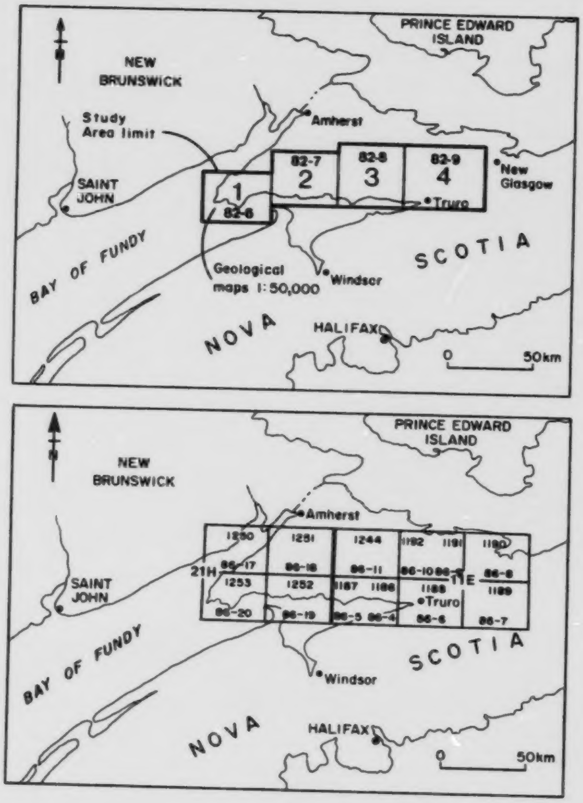

PRINCE EDWARD ISLAND
NEW BRUNSWICK
Study Area limit
Amherst
SAINT JOHN
82-7
2
82-8
3
82-9
4
1
82-6
New Glasgow
Truro
BAY OF FUNDY
Geological maps 1:50,000
Windsor
SCOTIA
NOVA
HALIFAX
0
50km
PRINCE EDWARD ISLAND
NEW BRUNSWICK
Amherst
1250
1251
1244
1192
1191
1190
21H
86-17
86-18
86-11
86-10
86-9
86-8
11E
1253
1252
1187
1186
1188
1189
SAINT JOHN
Truro
86-20
86-19
86-5
86-4
86-6
86-7
BAY OF FUNDY
Windsor
SCOTIA
NOVA
HALIFAX
0
50km

Figure 1. Outline of study area: (a) geological maps of Donohoe and Wallace, 1982 and (b) NSDME Open File Map coverage.

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[1] Funded by Geological Survey of Canada under the Canada - Nova Scotia Mineral Development Agreement

[2] Geological Survey of Canada, 601 Booth Street., Ottawa, Ontario K1A 0E8

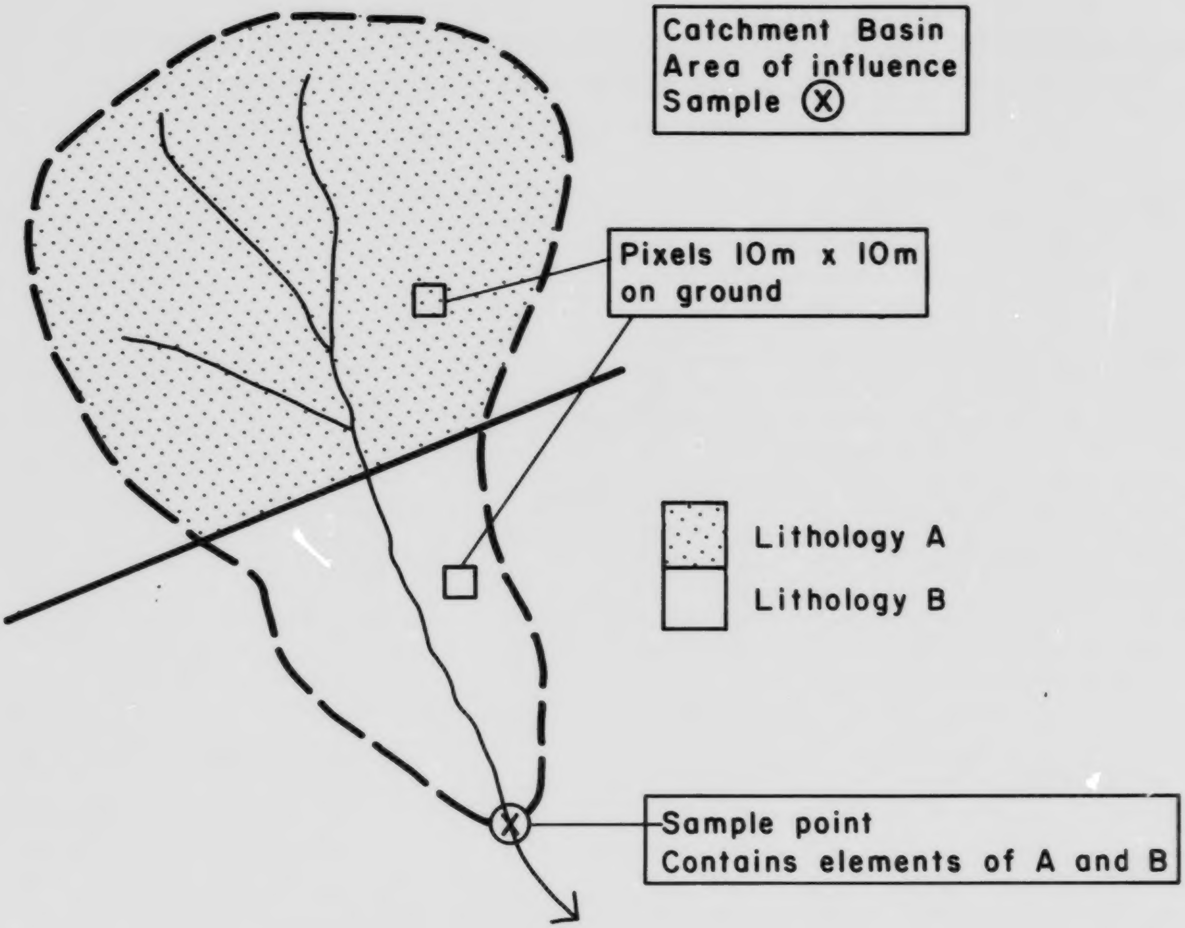
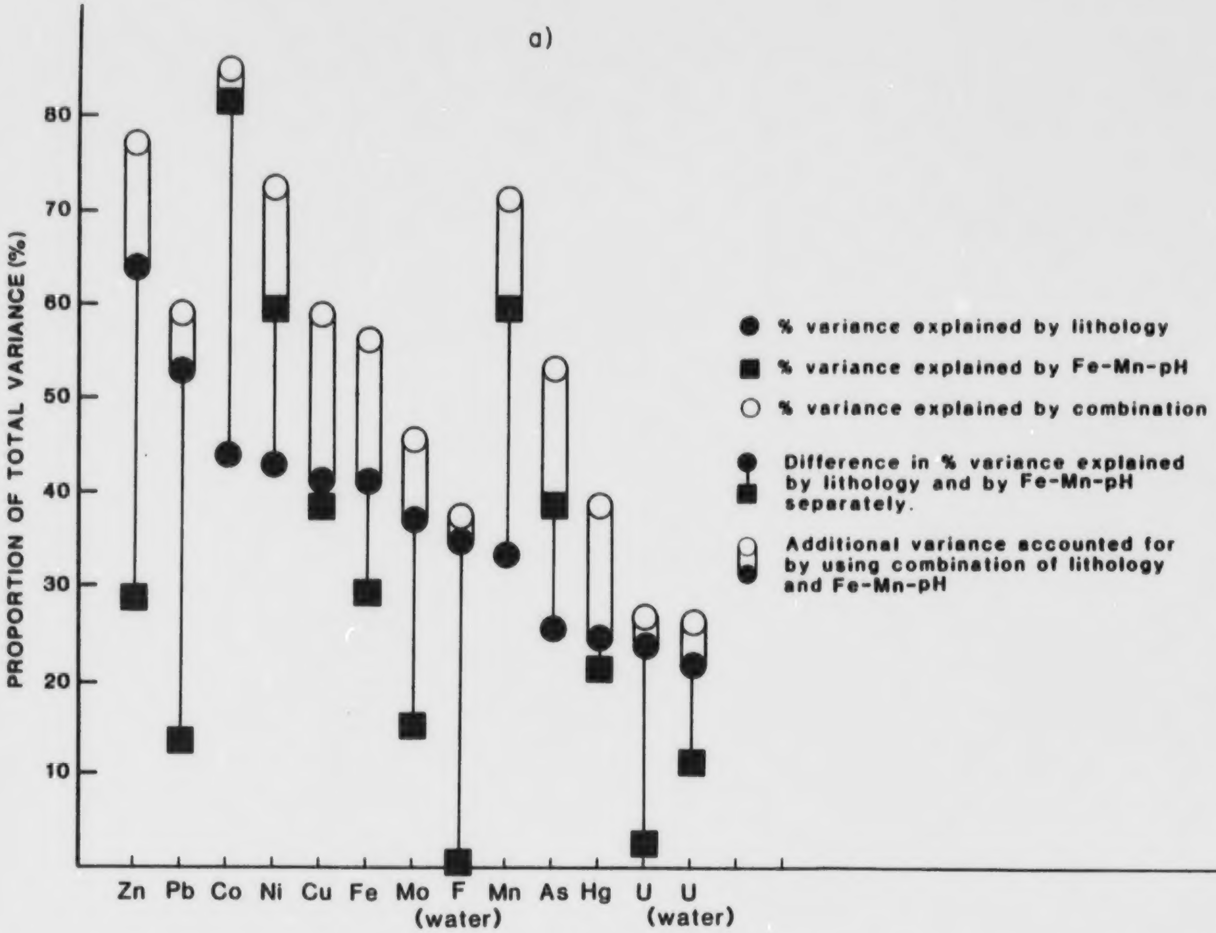


Figure 2. Conceptual model to show the relationship between the stream sediment sample and the lithological units within its boundaries.

A computer file was then created describing location, chemical composition, geology, total area, mineralization and commercial assessment follow up work for each polygon of the defined catchment basins.

For the Cobequid Highlands data, 25 - 65% of the total variance can be attributed solely to areal proportions of mapped geological units (Fig. 3). Scavenging of elements by Fe and Mn oxides and hydroxides in the secondary environment and pH effects are also modelled by this approach.

Exploration target definition was approached in a variety of ways using CBA. Percentile scale coloured maps from an ink jet plotter were made for each polygon with the elemental value as the theme filling the catchment basin. Step-wise regression using areal proportions of mapped units as independent variables modelled geochemical background to produce residual maps. After removal of catchment geology and scavenging variance, a residual map is plotted to define anomalous areas and improve target selection by avoiding investigation of spurious anomaly patterns, especially for Fe-Mn-Ni-Co-As-Cu and Cu-Pb-Zn. The first 3 principal components of the logarithms



b)

Lithology	Mean ppm Zn
Diabase	155
Wolfville Fm.	41
Pictou Gp.	83
Cumberland Gp.	57
Parrsboro Fm.	85
Millsville Cong.	83
Canso Gp.	68
Londonderry Fm.	105
Granite	143
Granite	144
Granite	136
Windsor Gp.	35
Horton Gp.	58
Falls Fm.	56
Nuttby Fm.	131
Granite	146
Diorite	171
Fountain Lake Gp.	73
Fountain Lake Gp.	82
Byers Brook Fm.	140
Byers Brook Basalt	166
Fountain Lake Gp.	77
Fountain Lake Gp.	80
Grey Diorite	117
Syenite	148
Syenogranite	73
Granite	142
Earltown Fm.	88
Ord-Silurian	138
Ord-Silurian	104
Syenogranite	144
Warwick Mtn. Fm.	129
Folly River Schist	129
Gamble Brook Schist	142
Mt. Thom Complex	107

Figure 3(a). Summary of regression experiments for each element. For example, 64% of Zn variation can be explained using areal proportions of map units in catchment basins; 29% of Zn variation can be explained by Fe-Mn-pH variables alone; 78% of the variation is explained by map variables plus Fe-Mn-pH.

Figure 3(b). Weighted mean concentrations for Zn in streams draining some of the Cobequid study area map units derived from regression experiments (from Rogers et al., 1986 and Bonham-Carter et al., 1987).

of the element data (explaining 64% of variance) are plotted as factor scores with each factor as one of 3 primary colours (Fig. 4). Factor score plots identified broad regional geochemical trends as distinct domains often related to large structural features and specific stratigraphic units (Fig. 5). The 90th percentile values from each polygon were compared to anomalous soil values or known mineralization to identify "explained" anomalous values for each element. Further target selection included polygons containing known mineralization and detailed soil sampling grids. Anomalous catchments have polygons with "explained" elemental patterns which when removed from the analysis, leave areas of unexplained patterns with unsuspected exploration potential.

CBA applied to mineral exploration in this area which has been subject to much prospecting, significantly aids in target selection for anomalous areas and detection of previously unsuspected mineral potential in areas that have not been prospected extensively.

Targets for Au and Cu-Pb-Zn have been identified in Carboniferous sedimentary basins and contact areas of Devono-Carboniferous volcanics and granites in Nova Scotia using CBA.

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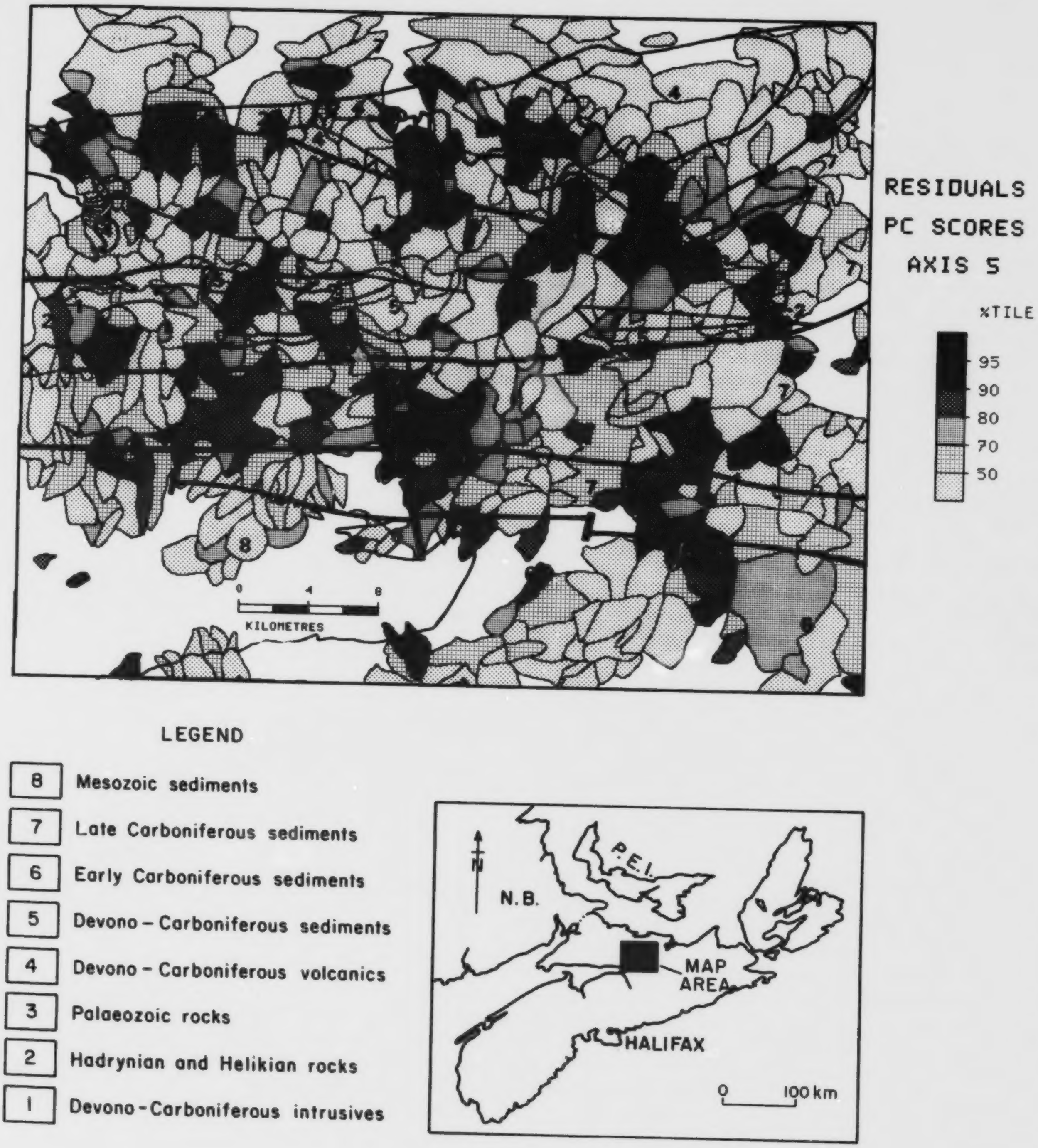
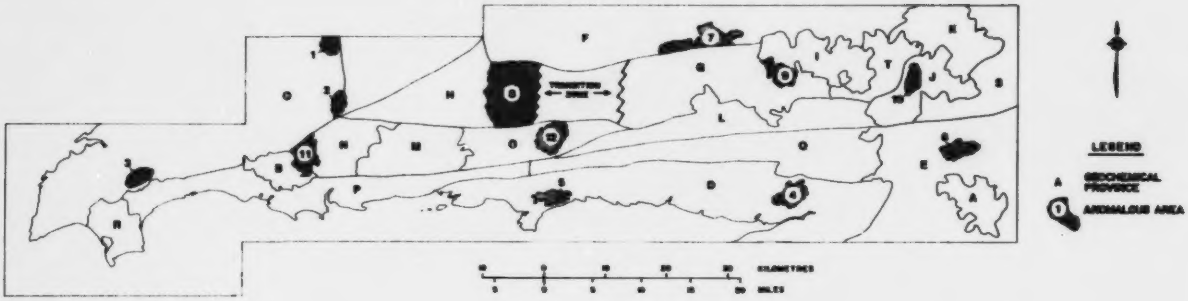

RESIDUALS
PC SCORES
AXIS 5
%TILE
95
90
80
70
50
0
4
8
KILOMETRES
LEGEND
8 Mesozoic sediments
7 Late Carboniferous sediments
6 Early Carboniferous sediments
5 Devono – Carboniferous sediments
4 Devono – Carboniferous volcanics
3 Palaeozoic rocks
2 Hadrynian and Helikian rocks
1 Devono-Carboniferous intrusives
N
N.B.
P.E.I.
MAP AREA
HALIFAX
0
100 km

Figure 4. Applicon computer plot of PC5 scores (residuals, after regression) for Cu-As by catchment basin areas.


F
7
K
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TRANSITION ZONE
J
S
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L
12
O
N
M
11
B
P
5
D
4
E
A
R
3
6
LEGEND
A GEOCHEMICAL PROVINCE
1 ANOMALOUS AREA
KILOMETRES
MILES

Figure 5. Map showing the various geochemical provinces identified from the principal component colour computer plot and some of the anomalous areas.

REGIONAL GEOCHEMICAL SURVEYS[1]

R. F. Mills

INTRODUCTION

A regional stream sediment survey was carried out on the northern mainland of Nova Scotia and on Cape Breton Island in 1986 and 1987 to provide analytical data on stream water and two fractions of stream sediment (Fig. 1). Approximately 3300 stream sediment samples, including duplicates, were analyzed for 30 elements in the coarse (-60+230) heavy mineral separate fraction and 16 elements in the fine (-230) fraction yielding a total of approximately 152,000 analytical results. Some of these analyses are supplemented with fire assay analyses for gold. Stream waters were analyzed for U by fluorimetry and for F by specific ion electrode methods. Conductivity and pH measurements were also taken to help understand the digestive nature of some Nova Scotia streams and their possible relation to terrain and(or) acid rain. The aim of these surveys is to provide a database for the northern part of the Province as part of the compilation of a Nova Scotia Geochemical Atlas.

SAMPLING TECHNIQUE

Stream sediment samples were passed through a -18 mesh nylon screen in the field and collected in a plastic pan along with all of the water used during sieving. The -18 mesh sample and water were then poured into a 3 ml gauze polythene bag. This field sampling procedure minimizes loss of fine gold by saving the water used during sieving. Boyle (1979) has shown that water used during sieving may carry away fine gold. Air was removed after the samples were placed on a table for at least 48 hours to allow the fine gold to settle. Excess water was then siphoned out of the bags and samples were packed for transport to the preparation lab where they were washed and sieved into the respective coarse and fine fractions. The coarse fraction was also separated into a heavy mineral concentrate for instrumental neutron activation analysis (INAA). Stream waters were collected in 250 ml plastic bottles and shipped to the analytical lab directly.

ANALYSIS

Two size fractions from each sample were analyzed. The -230 (fine) fraction was analyzed for a suite of precious and base metals, and their granophile, siderophile and chalcophile indicators. The -16+230 heavy mineral (coarse) fraction was separated with methyl iodide and analyzed for a similar set of elements (Fig. 2).

Erratic results from neutron activation analysis for gold resulted from methods of heavy mineral separation used during sample preparation in 1986. A residue of bromine left in some samples after tetrabromoethane heavy mineral separation produced erratic gold results (Lombard and Mills, 1987). Gold analytical values that were inaccurate were replaced by results from fire assay analysis performed on the 1986 samples.

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[1] Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

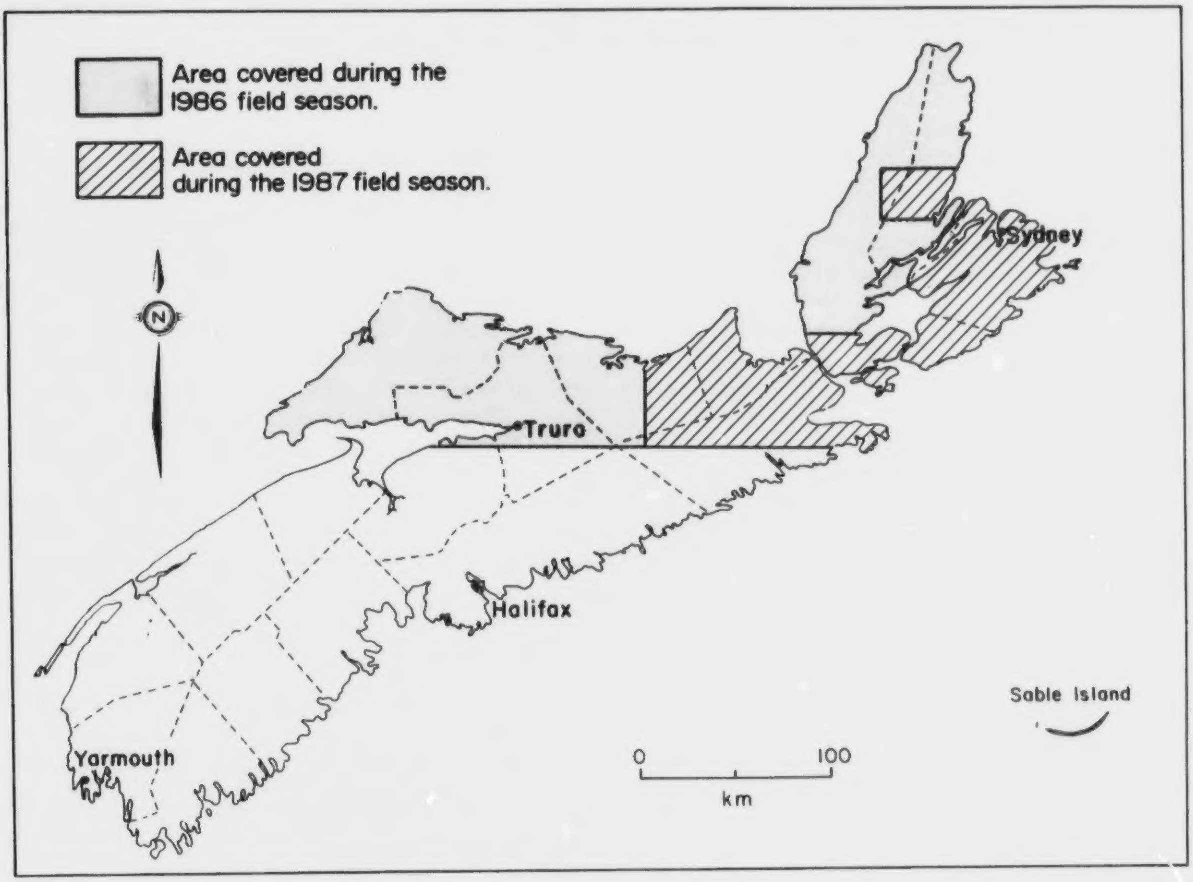
Area covered during the 1986 field season.
Area covered during the 1987 field season.
N
Sydney
Truro
Halifax
Yarmouth
Sable Island
0
100
km

Figure 1. Field areas sampled during 1986 and 1987, after Lombard and Mills (1987).

The laboratory procedure for the 1987 field samples used methyl iodide (iodomethane) that was diluted with acetone to the same specific gravity as tetrabromoethane (S.G. 2.95) as the separation medium so that results from both years would be comparable. This was determined from a pilot study performed in 1987 to determine which separation medium is most suitable for extracting heavy minerals from stream sediments in Nova Scotia (Lombard and Mills, 1987).

Stream waters were filtered through a 45 µm filter and analyzed for U by fluorimetry and F by specific ion electrode.

QUALITY CONTROL PROCEDURES

The sample vials were grouped into analytical batches consisting of 20 consecutively numbered samples. Included in every batch were 2 randomly chosen field duplicates, an analytical duplicate and a standard. Field duplicates determine field site variation, analytical duplicates measure analytical precision and the standard measures the accuracy of the laboratory. Stream waters were the only exception to this format. It was not practical to have an analytical duplicate (split sample), so the field duplicate is used in the same manner.

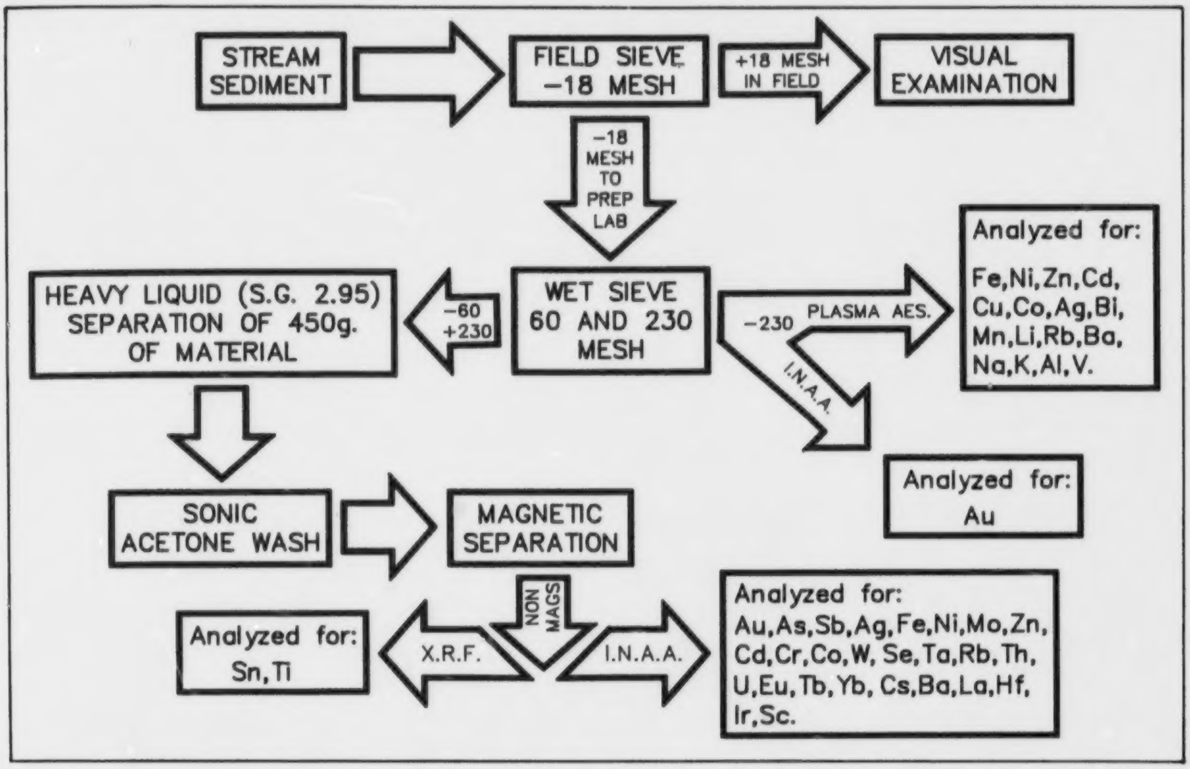
STREAM SEDIMENT
FIELD SIEVE −18 MESH
+18 MESH IN FIELD
VISUAL EXAMINATION
−18 MESH TO PREP LAB
WET SIEVE 60 AND 230 MESH
−60 +230
HEAVY LIQUID (S.G. 2.95) SEPARATION OF 450g. OF MATERIAL
−230
PLASMA AES.
I.N.A.A.
Analyzed for: Fe,Ni,Zn,Cd, Cu,Co,Ag,Bi, Mn,Li,Rb,Ba, Na,K,Al,V.
Analyzed for: Au
SONIC ACETONE WASH
MAGNETIC SEPARATION
NON MAGS
X.R.F.
I.N.A.A.
Analyzed for: Sn,Ti
Analyzed for: Au,As,Sb,Ag,Fe,Ni,Mo,Zn, Cd,Cr,Co,W, Se,Ta,Rb,Th, U,Eu,Tb,Yb, Cs,Ba,La,Hf, Ir,Sc.

Figure 2. Flow chart of sample preparation and analysis, after Mills et al. (1986).

PRIMARY AND SECONDARY DATA ANALYSIS

The database consists of several parts. First, preliminary statistics are run on each dataset to insure proper laboratory control. For each year a digitized location file is merged with:

(a) the analyses file from the stream sediment heavy mineral concentrate (for 1986 and 1987),
(b) the fine fraction analyses file (for 1986 and 1987),
(c) the stream water analyses file (for 1986 and 1987),
(d) a text file including sample site information (for 1986 and 1987) and
(e) the 1986 fire assay file.

This produces nine separate merged files (Fig. 3). All analyses files for the two years are merged to produce five files, four for the two-year merged files and a separate 1986 fire assay file (Fig. 3). Then each type of analysis is sorted into its appropriate 1:250 000 map sheet resulting in 20 new and separate datasets. After standards and outliers are removed from the datasets further univariate and bivariate statistics, such as catchment basin analysis and regression analysis, can be applied. Each of these four map sheet files will be plotted and presented separately (Fig. 3).

The digitized analytical data files will be presented as 1:250 000 scale map sheets. Thresholds will be set for each statistical population in each map sheet and will be presented as probability plots with histograms and(or) box and whisker plots to give atlas users insight into more local anomalous values.

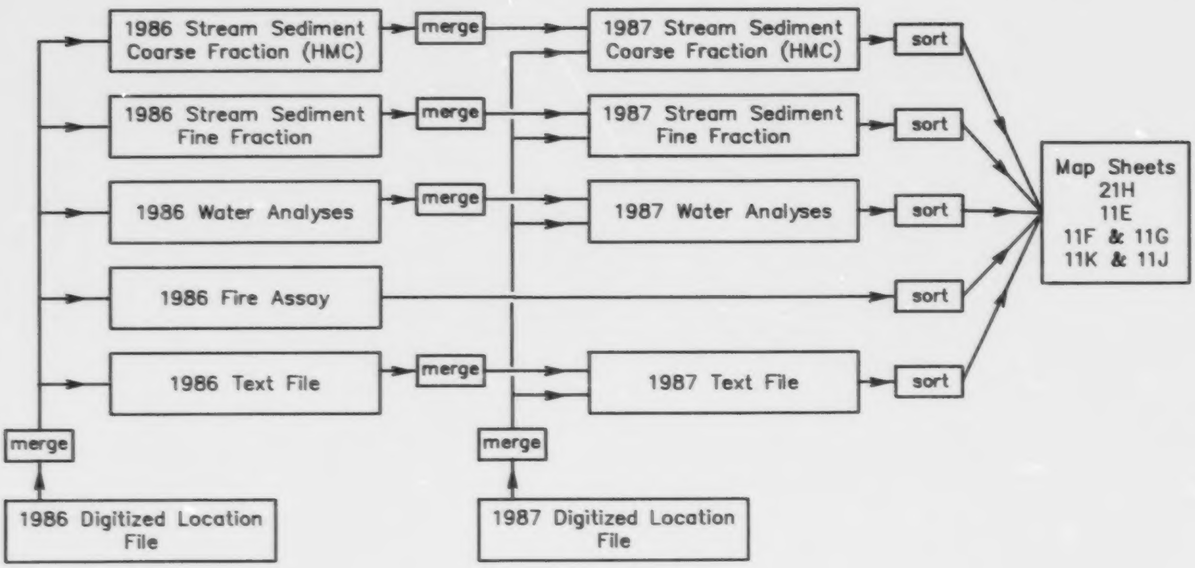
1986 Stream Sediment Coarse Fraction (HMC)
1986 Stream Sediment Fine Fraction
1986 Water Analyses
1986 Fire Assay
1986 Text File
merge
1986 Digitized Location File
1987 Stream Sediment Coarse Fraction (HMC)
1987 Stream Sediment Fine Fraction
1987 Water Analyses
1987 Text File
1987 Digitized Location File
sort
Map Sheets
21H
11E
11F & 11G
11K & 11J

Figure 3. Simplified flow chart of generation and manipulation of computer files to produce separate map sheets, scale 1:250 000.

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QUATERNARY MAPPING IN THE ANNAPOLIS VALLEY[1]

R. R. Stea and R. G. Turner

The Quaternary geology of part of the Annapolis Valley (mainly the 21A/14 map sheet) was mapped during the summer of 1988 (Fig. 1). The field data collected will be used to check surficial contacts established by previous mappers (Hickox, 1962; Trescott, 1968) and to re-evaluate the depositional history of the area. When data compilation is completed, a 1:50 000 surficial geology map and a summary report will be produced.

At each stop glacial deposits were described and altimeter readings recorded. Samples were collected at many of the sections for grain size anlyses of the clay and clay diamicton and for dating of buried organics. A brief description of the striations and some of the glacial deposits mapped are given below.

STRIATIONS

Three prominent directions of striations were mapped: 120° , 320° and 290°. Several outcrops in the eastern portion of the valley record a late 250° striation set. The sense of ice flow direction was determined using features such as stoss and lee bedrock topography, nailheads and mini crag and tails.

RESIDUUM

Deposits of residuum (possibly saprolite) were found on the steep side of the North Mountain cuesta. In this location basaltic rock is weathered to its end products, kaolinite and iron oxide.

TILL

The surface till throughout the map area is typically reddish-brown and has a silty-clay matrix. Clasts include sandstone from the Blomidon and Wolfville Formations and basalt from the North Mountain formation. Boulders of South Mountain Batholith provenance are found on the North Mountain as are diorite and syenogranite from the Caledonian Highlands.

ICE-CONTACT SEDIMENTS

Most ice-contact deposits occur on the north flank of the South Mountain Batholith and many are presently being quarried for sand and gravel. An ice contact complex mapped by Hickox (1962) at Round Hill is interpreted as deltaic with well defined foresets and bottomsets. The ice front appears to have been against the adjacent South Mountain as there are proximal ice contact deposits found there containing large blocks of South Mountain Batholith granite.

CLAY AND SILTY-CLAY DIAMICTON

A thick, massive red clay covers the western portion of the map sheet. In the past this clay was used as fire clay, brick and potters clay. At several sites a silty-clay diamicton of uncertain genesis is exposed. These sites were found at different elevations, from 15 to 60 m above MSL. The diamicton is massive, moderately compact and has abundant well-rounded clasts and few striated clasts. Fabrics

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[1] Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

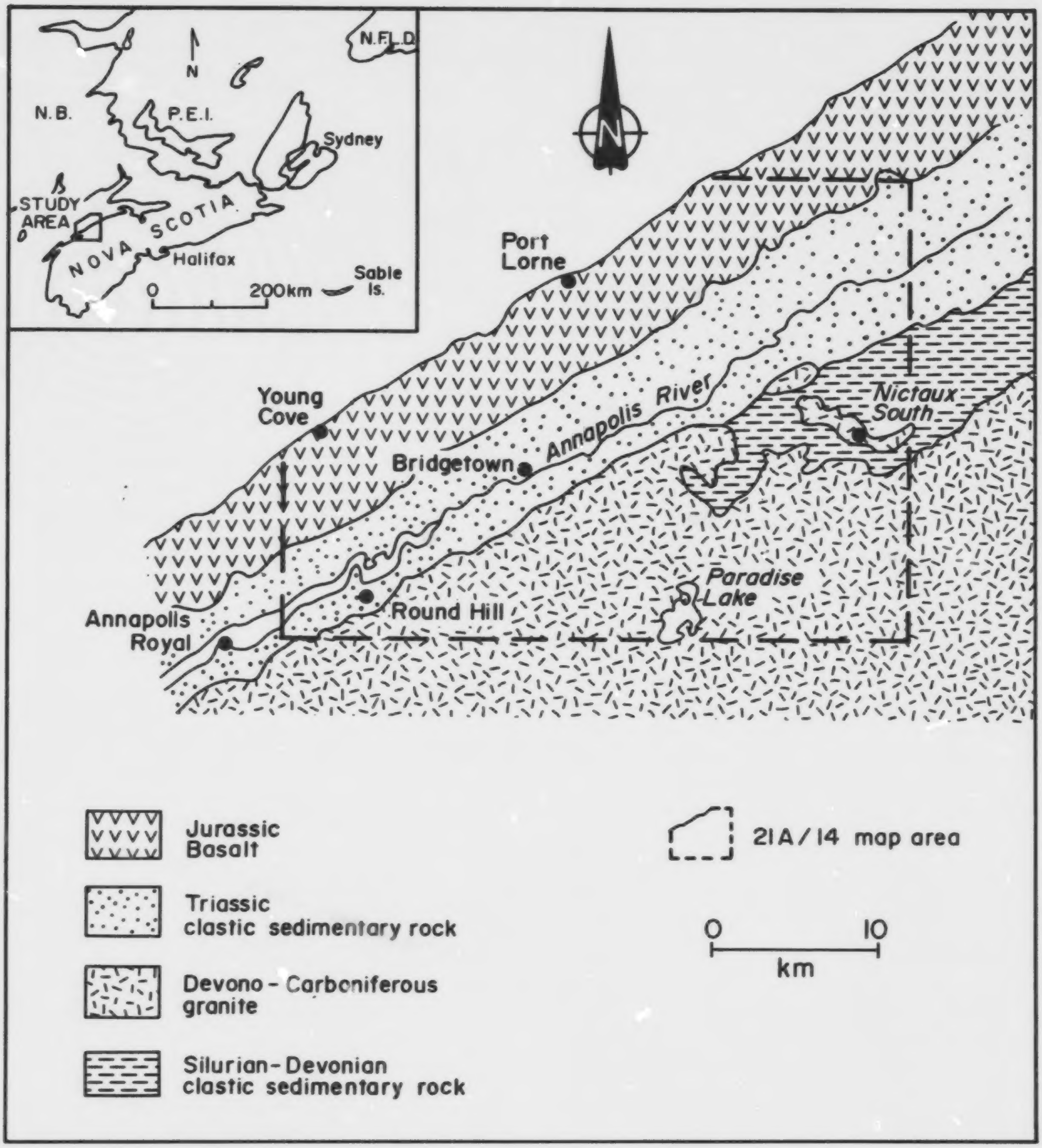
N.FLD.
N
N.B.
P.E.I.
Sydney
STUDY AREA
NOVA SCOTIA
Halifax
0
200km
Sable Is.
N
Port Lorne
Young Cove
Bridgetown
Annapolis River
Nictaux South
Paradise Lake
Round Hill
Annapolis Royal
Jurassic Basalt
Triassic clastic sedimentary rock
Devono - Carboniferous granite
Silurian-Devonian clastic sedimentary rock
21A/14 map area
0
10
km

Figure 1. Location and general geology of the 21A/14 map sheet.

were measured at one site flanking the North Mountain at an elevation of 60 m.

This diamicton exhibits a strong unimodal fabric and is therefore considered a till. A break in elevation between the clay and the diamicton occurs around 27 m.

MODERN ESTUARINE

A traverse along the Annapolis River from Bridgetown to Annapolis Royal enabled examination of the stratigraphy along the banks. Generally an unfossiliferous, reddish, laminated clay-silt-sand is overlain by organic clay, which is overlain by peat with grass and wood fragments, capped by a bedded grey clay-sand and reddish laminated clay-sand. At one locality, exposed at low tide, a layer of large, upright tree stumps was truncated by modern estuarine sediment.

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THE EDUCATION AND PUBLIC AWARENESS PROGRAM IN THE DEPARTMENT OF MINES AND ENERGY[1]

H. V. Donohoe, Jr. and M. E. Devanney

INTRODUCTION

Public awareness of Nova Scotia's mineral resources, geology and mineral industry is an important component of the work and mandate of the Nova Scotia Department of Mines and Energy. This awareness is developed through education.

PREVIOUS WORK

The Department has had staff associated with education programs at various times over the past 80 years. The earliest work in public awareness started about 1900 with the preparation of a Nova Scotia rock and mineral collection by Henry Piers for the Paris Exhibition and the Chicago World's Fair. During the 1930s a former deputy minister, J. P. Meservey, began an education program with still photography and 16 mm films of mining activities in different parts of Nova Scotia. He later prepared brochures on various mineral commodities which occur in the Province. Meservey wrote a booklet about the mining history of Nova Scotia and a road guide to the rocks, minerals, landforms and mines adjacent to or on the main highways of the Province.

In the early 1950s, the Department began a long, productive association with various American and Canadian universities in training geology students through the provincially owned "Crystal Cliffs Field School" near Antigonish. Although the land and buildings are no longer owned by the Province, the Department still supports field schools for geology students.

Training for the general public was made available in the 1960s with prospecting courses held in different parts of the Province. Instruction was provided with the help of Frank Shea from the Department and Clint Milligan and Basil Cooke from Dalhousie University.

The Department prepared its first major public display, Georama, for the International Geological Congress at Montreal in 1972. In the middle 1970s, Diane Gregory, a geologist with the Department, began the preparation of pamphlets, a bibliography and a series of exploration and mining pictures. Her work resulted in the publication of the pamphlets *Geology, Minerals and Mining* and *History of Coal Mining in Nova Scotia*.

By the early 1980s the Department was convinced by the problems associated with the debate on uranium exploration and the successful Nova Scotia Department of Mines and Energy, Energy Branch information program that better public education was essential. The Mines and Minerals Branch of the Department established the Education and Public Awareness Program in the Mineral Resources Division as a full time operation to provide assistance and information to the public.

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[1] Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

MANDATE

The mandate of the Education and Public Awareness Program is to describe, interpret, publicize and promote the mineral resources, geology and mineral industry in Nova Scotia. With the signing of the Canada - Nova Scotia Mineral Development Agreement (CNSMDA) in June of 1984, describing and promoting the Agreement and each of the five programs became part of the Group's mandate.

In addition to the work in the Mines and Minerals Branch, the Education and Public Awareness Group became the Provincial representative on the Public Information Subcommittee of the CNSMDA. The Subcommittee manages the activities of the Public Information Program in the CNSMDA.

OBJECTIVES

With this increased mandate, the Education and Public Awareness Group has three objectives which govern its work. The first is to describe and promote the CNSMDA so that exploration and mining companies, government agencies and the general public are aware of its programs, sources of information, project results and importance to the Province.

The second objective is to provide information about the mineral industry in Nova Scotia to teachers and students in schools and universities, government agencies and the general public by: (1) showing the importance of this natural resource sector compared to the other three resource sectors, (2) describing its importance within the total provincial economy and (3) assisting schools and the general public in obtaining information about the mineral industry.

Providing information about the geology, minerals and landforms of the Province is the third objective in developing and implementing a Public Information Program. Teachers, students, visitors, residents and government agencies are the targets for this information.

METHODS OF DELIVERY

The presentation of information may be through direct contact with geologists from the Education and Public Awareness Group or it may be indirect. Members of the Group make direct contact with teachers through inservices, fieldtrips, and classroom appearances. Visitors and residents, as well as school classes, take advantage of the many walking tours held in co-operation with the Nova Scotia Museum in the summer and fall. Prospecting classes are another means of working directly with user groups. A large number of people see the Group's displays at exhibitions and shopping malls throughout Nova Scotia.

The brochures, videos, newsletters, booklets and teaching resources are examples of assisting user groups with information through an indirect approach.

All of the work undertaken by the Education and Public Awareness Group for the CNSMDA is co-ordinated with its federal counterpart, the Regional Manager, Communication Branch, Energy Mines and Resources Canada (EMR).

ACTIVITIES

With Departmental and CNSMDA responsibilities, the Education and Public Awareness Group has a large number of activities. These range from leading walking tours to preparing publications to working with mining and education groups in preparing a loan kit for teaching more about mining.

PROMOTION OF THE CNSMDA

One of the more important parts of our work is making certain that the general public, exploration and mining companies and government agencies are aware of CNSMDA programs. This is mostly accomplished through general and technical displays in Nova Scotia and elsewhere in Canada as well as brochures and advertisements. Some programs need publicity, such as the Mineral Investment Stimulation Program (MISP), to keep the many potential users aware of its opportunities. A proper identification of the CNSMDA through the use of its logo and word mark are essential parts of identity and promotion.

DISPLAYS

Displays are an important means of directly bringing information about, and promotion of, the CNSMDA and mineral industry to a wide audience. Nineteen general and three technical displays were prepared for showing at exhibitions and shopping malls in Nova Scotia and at technical meetings in Halifax and Toronto (Table 1).

The displays emphasize the various programs of the CNSMDA and their importance, the mineral industry of Nova Scotia and its importance to the economy, and the rocks, minerals and geology of the Province. More than 22,000 people will have seen the various displays by the end of the 1988-89 schedule.

WALKING TOURS

The purpose of walking tours is to highlight the rocks, minerals, landforms, building stones and/or mineral industry of a part of Nova Scotia. This is accomplished by using local, municipal and provincial parks, visitor attraction areas, and selected streetscapes in cities or towns (Table 2). All of the work in developing and promoting the walking tours is in co-operation with the Nova Scotia Museum.

Walking tours are one of the best ways to directly interact with a variety of people to describe, discuss and promote the mineral resources, geology and mineral industry in the Province. More than 250 people have participated in the 14 walking tours this year.

EDUCATION

The Education and Public Awareness Group have been providing a continuing service to teachers, educators, students, residents and visitors with inservice seminars, talks, lectures, courses and elderhostel programs. The subjects of these presentations include all or part of the following:

(1) rocks, minerals and geological evolution of the Province,
(2) mining history and the present day mineral industry,
(3) methods of instruction for earth science subjects,
(4) how to use the mining loan kit from the Nova Scotia Museum,
(5) methods of prospecting and
(6) introduction to structural geology field methods.

The Department is continuing its long tradition of assistance to university geological field schools. Staff of the Education and Public Awareness Group teach a unit on structural field methods each spring at the geological field school held at Saint Francis Xavier University.

Seminars and talks to specialty groups and the general public allow staff to describe and discuss a variety of subjects. The Eastern Shore Board of Trade was briefed on the geology, mineral resources, mining history and present mineral exploration and development along the eastern shore. Sheet Harbour was the site of a seminar about gold exploration and mining. The Nova Scotia Teachers Union, Truro Local Education Committee, invited the Education and Public Awareness Group to present teachers with an inservice describing the resources of Victoria Park based on the walking tour.

Table 1. The 1988-89 display schedule.

Date(s)	Location	Event/Site
June 3	Halifax	Halifax Shopping Centre
June 10, 11, 12	Windsor	N. S. Forestry Exhibition
June 23, 24, 25	Baddeck	Cape Breton Resource Exhibition
June 27, 28, 29	NSDME-EMR JOINT DISPLAY TOUR 1	
27	Amherst	Amherst Centre Mall
28	Truro	K-Mart Mall
29	New Minas	Towers Mall
July 12, 13, 14, 15	NSDME-EMR JOINT DISPLAY TOUR 2	
12	Port Hawkesbury	Port Hawkesbury Shopping Centre
13	Sydney	Sydney Shopping Centre
14	Antigonish	Antigonish Shopping Centre
15	New Glasgow	Aberdeen Mall
August 12, 13, 14	Parrsboro	Rock Hound Round Up
August 17,18,19,20	Upper Musquodoboit	Halifax County Exhibition
August 24, 25	NSDME-EMR JOINT DISPLAY TOUR 3	
24	Bridgewater	Bridgewater Mall
25	Yarmouth	K-Mart Plaza
Sept. 1, 2, 3	Halifax	Prospecting in Areas of Glaciated Terrane (PAGT)
Oct. 13, 14, 15, 16	Halifax	Atlantic Winter Fair
October 21	Halifax	Association of Science Teachers
November 16, 17	Halifax	NSDME Open House
March 5, 6, 7, 8	Toronto	Prospectors and Developers Association of Canada (PDAC)

A new aspect of education work has been the development of seminars for elderhostels. Retired people from Nova Scotia, elsewhere in Canada and the USA attend one week sessions on various subjects. Three half day and two full day seminars have been presented this year about gold, gold mining and exploration on the eastern shore and the geology and landforms of the Tatamagouche area.

The Education and Public Awareness Group, Nova Scotia Museum and the Chamber of Mineral Resources of Nova Scotia have been working together to develop the Mining Kit for lending to teachers in support of the grade 8 unit, "Science in Mining". The Kit contains videos of salt and tin mine operations, rock and mineral samples, slides, a teachers' resource guide, brochures and maps, and information from production companies.

A prospecting course has been held for the past several years in conjunction with the Chamber of Mineral Resources of Nova Scotia. It is being developed for presentation at numerous locations in the Province. An advanced course will be presented at a future date.

PUBLICATIONS

Many publications have originated from the CNSMDA Public Information Program and more are planed. All of the walking tours are described in

Table 2. The 1988 walking tour schedule.

May 11	Halifax	Downtown building stones
May 25	Halifax	Rocks and landforms of Point Pleasant Park
June 1	Halifax	Building stones of Spring Garden Road
June 15	Peggys Cove	Rocks and landforms of Peggys Cove
June 29	Truro	Rocks and landforms of Victoria Park
July 6	Peggys Cove	Rocks and landforms of Peggys Cove
July 20	Halifax	Building stones of downtown Halifax
July 24	Truro	Rocks and Landforms of Victoria Park
August 3	Halifax	Rocks and landforms of Point Pleasant Park
August 6	Five Islands	Rocks and landforms of Five Islands Provincial Park
August 17	Truro	Building stones of Prince Street
August 31	Truro	Rocks and landforms of Victoria Park
September 14	Halifax	Building stones of Spring Garden Road
September 21	Dartmouth	Rocks and landforms of Dartmouth Commons

brochures. Regulations and guidance to prospectors and exploration companies are contained in information brochures. By the end of the fiscal year several new publications will be ready for teachers, geologists and the general public. These include the Geological Guide to Nova Scotia, revised Geological Highway Map of Nova Scotia, and the Mineral Resources Atlas of Nova Scotia.

CONCLUSIONS

The activities of the Education and Public Awareness Program support the CNSMDA and departmental mandate for informing the public about the importance of Nova Scotia's mineral industry, the CNSMDA and the geology and mineral resources of the Province.

ACADIA UNIVERSITY: DEPARTMENT OF GEOLOGY RESEARCH

J. A. Colwell, Head

Acadia University is located at Wolfville, Nova Scotia, in the eastern Annapolis Valley about 100 km northwest of Halifax. The Geology Department consists of 7 full-time professors, 1 part-time lecturer, and 1 demonstrator. New appointments include Dr. Gary Yeo as a sabbatical replacement for three years, Dr. Kelsey Dadd as post doctoral fellow and Dr. Richard Jones as honourary research associate. We have 40 undergraduate majors and 10 graduate students.

The Geology Department emphasizes an integrated field and laboratory approach and offers instruction and research training leading to the four year degrees Bachelor of Science and Bachelor of Science with Honours, and the Master of Science degree. Research funding mainly comes from faculty grants and contracts which are held by most staff. All full-time graduate students also hold fellowships.

Research conducted by the faculty and students is diversified. However, our main thrust is in Nova Scotian geology with various projects involving economic geology, igneous petrology, metamorphic petrology, geochemistry, volcanology, biostratigraphy, paleontology, sedimentology, ichnology, structural geology, regional geology and basin analysis.

RESEARCH PROJECTS IN NOVA SCOTIA

S. M. Barr - Continued regional mapping program in Cape Breton Island. Related petrologic studies emphasize granitoid and volcanic units.

B. W. Cameron - Barrier island development; paleontology and stratigraphy of the Scots Bay and Blomidon formations; freshwater and salt marsh peats.

J. A. Colwell - Mineral deposits; clay mineralogy, geology of the North Mountain basalt; zeolites.

R. G. Moore - Biostratigraphy of the Windsor Group; geological mapping in the Mosherville, Rawdon and Clarksville areas.

R. P. Raeside - Regional mapping and tectonics of Cape Breton Island; metamorphism of Meguma Group, southwest Nova Scotia.

G. R. Stevens - Structural geology, southwest Nova Scotia; rock fabric; meteor impact.

N. A. Van Wagoner - Physical volcanology of the Fourchu Group, Cape Breton Island, in order to determine the paleovolcanic setting of these rocks.

G. M. Yeo - Carboniferous geology of Stellarton Gap area; coal studies in Pictou Coalfield.

M. Sc. THESES IN PROGRESS

Sedimentology of the Lower Stellarton Units, Pictou County, Nova Scotia. (L. Daigle)

Seismic stratigraphy of part of the upper continental slope off the central Scotian Shelf: Late Mesozoic to Cenozoic sequences. (E. Mutunga)

The geology of the George River Group, Creignish Hills, Cape Breton. (J. Campbell)

Basin analysis of the Late

Carboniferous, Upper Cumberland Group-Pictou Group transition of the west-central Cumberland Basin. (A. Deal)

Petrology and petrogenesis of Precambrian dioritic and tonalitic plutons of east-central Cape Breton Island. (C. Farrow)

M. Sc. THESES COMPLETED IN 1988

Geology of the Sporting Mountain area, southeastern Cape Breton Island, Nova Scotia. (A. Sexton)

The Deep Cove granite and associated Cu-Mo-Ag-Bi mineralization, southeastern Cape Breton Island. (F; Dennis)

Sedimentology and depositional environments of the Thorburn Member of the Stellarton Group in Nova Scotia. (R. Snow)

Petrology of the Black Brook Plutonic Suite and associated gneisses,Cape Breton Highlands. (W. Yaowanoiyothin)

B. Sc. THESES IN PROGRESS

Geology of Whycocomagh Mountain. (A. Armitage)

B. Sc. THESES COMPLETED IN 1988

Petrography and geochemistry of the Lowland Brook Syenite and associated rocks, Cape Breton Island, Nova Scotia. (S. Deveau)

Petrography and mineral chemistry of diopside, garnet and amphibole from carbonate and calc-silicate rocks, Cape Breton Island, Nova Scotia. (G. Walker)

ST. FRANCIS XAVIER UNIVERSITY
DEPARTMENT OF GEOLOGY

GENERAL

St. Francis Xavier University is located in Antigonish, about 250 km east of Halifax. The geology department consists of 4 staff members and approximately 30 undergraduate students.

The geology program is designed to provide a strong fundamental background for students who continue on to graduate study and at the same time enough operational practical training to equip those who are immediately employed as professional geologists.

The geology curriculum of the department reflects this aim. Courses such as Mineralogy, Crystallography, Petrology, Stratigraphy and Sedimentation, and Structural Geology are specialized and basic. Applied courses include Ore Deposits, Petroleum Geology, Coal Geology, Geophysics and Geochemistry. The latter provide an opportunity to use and to elaborate on the basic principles encountered in earlier geology courses and courses obtained outside this department, especially physics, chemistry and mathematics. There is a seminar course for senior students that is directed to developing the students' capacity to formulate a problem, devise a plan of attack, execute the plan and report the results orally and in written form. Figure 1 illustrates how the various courses are interwoven to form a coherent whole.

LABORATORY STUDIES

The field is viewed as the most important means of laboratory instruction. To bring together textbook and actual occurrence, certain laboratory periods are devoted to examination in the field. As expected, this is subject to seasonal restrictions.

In a number of branches of earth science, 3-dimensional visualization is extremely important. In Mineralogy, training in 3-dimensional visualization is promoted by the use of crystal models, lattice models and the examination of minerals in their actual crystalline form. In Structural Geology, 3-dimensional training is continued through the use of descriptive geometry and stereographic projection.

Other aspects of laboratory work include the examination of thin sections under the petrographic microscope, analyses of structures on maps and geochemical analyses including work on radiometric dating of rocks.

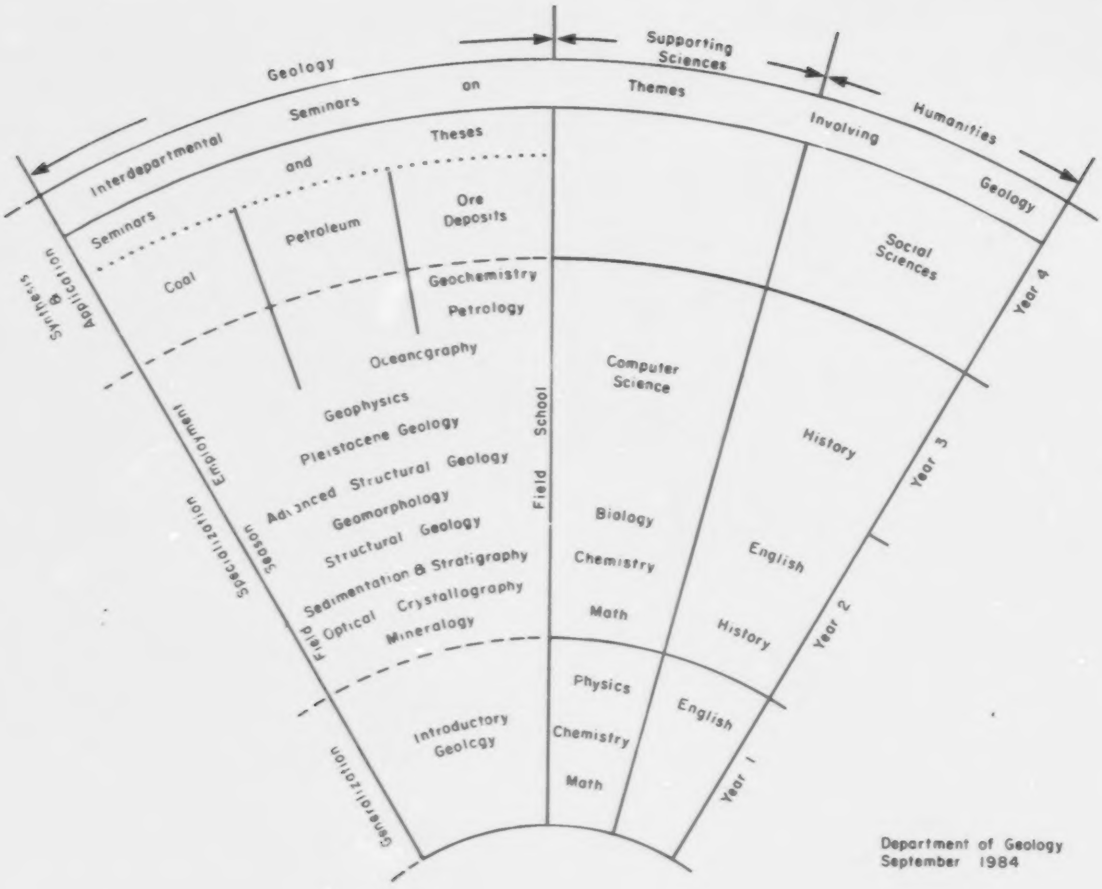
FIELD CAMP AND SUMMER EMPLOYMENT

At the end of the sophomore year all students are strongly urged to attend the 10-day spring field camp held annually at St. Francis Xavier University. The camp forms the core of the Field Methods course which also involves numerous mapping projects during sophomore, junior and senior years.

In addition, many geology students obtain employment in geological work during the summer. This is regarded as an effective extension of their classroom and laboratory experience.

FACULTY

Here is a brief outline of the geology staff at St. Francis Xavier University:


Geology
Supporting Sciences
Humanities
Interdepartmental Seminars on Themes Involving Geology
Seminars and Theses
Synthesis & Application
Coal
Petroleum
Ore Deposits
Geochemistry
Petrology
Oceanography
Geophysics
Pleistocene Geology
Advanced Structural Geology
Geomorphology
Structural Geology
Sedimentation & Stratigraphy
Optical Crystallography
Mineralogy
Introductory Geology
Employment
Specialization
Season
Field Season
Field School
Generalization
Computer Science
Biology
Chemistry
Math
Physics
Chemistry
Math
Social Sciences
History
English
History
English
Year 4
Year 3
Year 2
Year 1

Department of Geology
September 1984

Figure 1. Interrelationship of courses at Saint Francis Xavier University.

R. F. Cormier, Ph.D. (M.I.T.), has taught at St. Francis Xavier University for 30 years. He teaches introductory geology, geochemistry and historical geology. The age determination of rocks, using the ratio of radioactive rubidium to strontium, is his major research activity.

William S. Shaw, Ph.D. (M.I.T.), is Chairman of the department and teaches oil and gas geology, coal geology, stratigraphy and geophysics. He came to St. Francis Xavier University after a long career in oil exploration. Oil, coal, salt and ore deposits are his chief research interests.

J. Brendan Murphy, Ph.D. (McGill), teaches courses concerning the origin of igneous and metamorphic rocks, introductory and regional structural geology, optical mineralogy and tectonics. His research interests at present concern the geological evolution of the Antigonish and Cobequid Highland areas and the evaluation of its mineral potential.

Cynthia Murphy, M.Sc. (McGill), teaches mineralogy and is responsible for computer applications in geology. Her current interest is the geology of the Gaspe Peninsula in Quebec where she is studying the magmatic history of granitic and volcanic rocks.

MINERAL TECHNOLOGY AT THE UNIVERSITY COLLEGE OF CAPE BRETON: A CO-OP EDUCATION PROGRAM

H. R. Oldale

In September 1987, the Mineral Technology program at the University College of Cape Breton (U.C.C.B.) was converted to a 3-year co-operative education format and the first graduates are expected in 1990. The program includes five academic semesters and three four-month job placements (Table 1) leading to a Diploma in Mineral Technology with a co-operative endorsement. The program trains students in geology, mineral exploration, surface and underground mining, mineral processing and analytical chemical methods. Further information is available from the Co-operative Education office (902)539-5300, ext. 129 or the Mineral department (902)539-5300, ext. 191.

The curriculum objective of the Mineral Technology program since its inception in 1968 has been to provide a strong fundamental background for technical employment in the minerals, exploration, production and processing phases of the minerals industry. Since the first class graduated in 1970, some 133 students have obtained their diplomas and are employed throughout the country in all aspects of the mining and petroleum industries. Many of the earlier graduates now occupy senior technical and management positions.

Initial employment statistics (within three months of graduation) show approximately 20% of the graduates are employed in each of the exploration, mining and mineral processing phases of the mineral resources industry. Analytical laboratory work employs 10%, whereas another 10% are employed in mining-related occupations. Some 15% further their studies and the remaining 5% obtain employment in jobs unrelated to the minerals industry.

Some main features of the curriculum include: (1) a thorough grass roots field exploration project, (2) a complete mine feasibility project, (3) visits to most mining operations throughout the Atlantic provinces and (4) Extensive use of computer applications in all courses.

An industry advisory committee, meeting on an annual or bi-annual basis serves to keep the program current and up-to-date. The committee comprises some 16 senior personnel representing industry, government and educational institutions throughout Nova Scotia and New Brunswick.

FACULTY

F. M. Isenor, Dipl. T., B. Sc., a mining geologist, joined the department in 1981. He is a graduate of the Mineral Technology program and has had seven years industry experience in exploration work and coal mining geology. His teaching responsibilities include geology, surveying and assaying.

C. P. Nicholson, Dipl. T., is a graduate of the Mineral Technology program. He joined the faculty in 1981 after eight years experience in local mining and construction. His teaching duties include laboratory instruction in geology, mining, surveying, computers and exploration, in addition to laboratory maintenance and purchasing responsibilities.

H. R. Oldale, M. Sc., B. Ed., P. Eng., the senior member, joined the Department in December 1967 to set up

Table 1. Curriculum outline for the Mineralogy Technology program

SEPT - DEC	JAN - APR	MAY - AUG
Year 1		
Academic Term 1	Academic Term 2	Work Term 1
Math I	Math II	
Physics I	Physics II	
Communications I	Communications II	
Chemistry I	Chemistry II	
Geology I	Geology II	
Surveying I	Mining I	
	Computer Programming and Applications	
Year 2		
Academic Term 3	Work Term 2	Academic Term 4
Math III		Math IV
Geology III		Exploration Methods II (field project)
Mining II		Surveying II
Exploration Methods I		Assaying I
Mineral Process I		Mineral Process II
Drafting I		Drafting II
Year 3		
Work Term 3	Academic Term 5	
	Math V	
	Geology IV	
	Assaying II	
	Mining III	
	Exploration Methods III (mining project)	

the program prior to it opening in September 1968. Before 1967 he had spent ten years in geology, mine engineering, development and exploration management. He presently teaches geology and exploration methods.

H. E. Slaunwhite, B. Eng., B. Ed., P. Eng., a mining engineer, has taught in the program since 1969 after working 10 years in mining operations and industrial engineering. He presently teaches mineral processing, mining, computer and surveying.

PLANT FOSSILS FROM THE EARLY MESOZOIC FUNDY GROUP OF THE ANNAPOLIS VALLEY REGION OF NOVA SCOTIA[1]

B. Cameron[2] and J. R. Jones[2]

INTRODUCTION

The Upper Triassic to Lower Jurassic rocks of the Fundy Basin in the Annapolis Valley region of Nova Scotia (Figs. 1 and 2) have yielded very few plant fossils (Bock, 1969). From the Blomidon Formation, ferns were reported by Klein (1962) and a problematical plant was reported by Cameron and Jong (1985). From the Scots Bay Formation, tree trunks were reported as the nuclei of chert nodules (Cameron and Colwell, 1983; Cameron, 1985; Cameron et al., 1985). Some pollen and spore studies have also been conducted (Cornet, 1977; Hubert and Hyde, 1982; Cameron et al., 1985). Preliminary research has been conducted on the invertebrate fossils of the Fundy Group (Cameron, 1986; Cameron and Jones, 1987). As a consequence, our research efforts on the Fundy Group of the Annapolis Valley region have focused on paleobotany and invertebrate paleontology in addition to sedimentary environments.

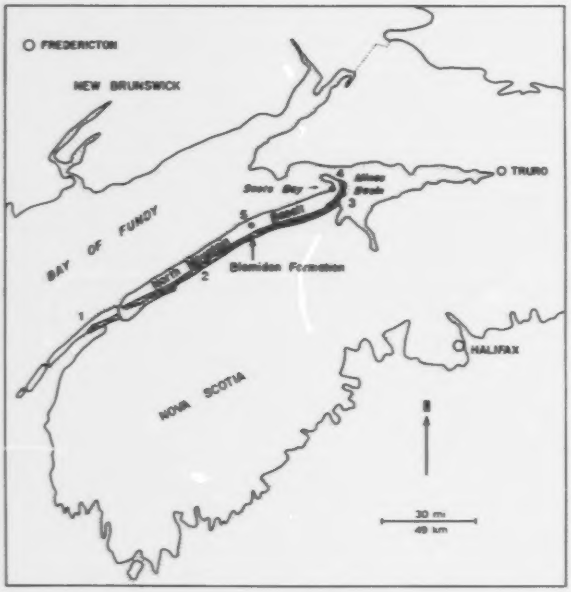


Figure 1. Plant fossil locality map: (1) Blomidon Formation at St. Marys Bay; (2) upper Blomidon Formation at Central Clarence; (3) lower Blomidon Formation at Delhaven and Blomidon; (4) Scots Bay Formation at Lime and Central Broad coves; (5) Getty Mines Ltd. well GAV 77-1 north of North Kingston.

This research project involves systematic collecting and measuring of exposures inland and along the coastlines of the western Minas Basin, southern Bay of Fundy and St. Marys Bay as well as drillcore from the Annapolis Valley and North Mountain regions (Fig. 1). Invertebrate and botanical fossils reported so far include ostracodes, conchostracans and problematical plant-like structures from the Blomidon Formation and ostracodes, bivalves, gastropods, charophytic algae, algal stromatolites and wood from the Scots Bay Formation (Cameron and Jong, 1985; Cameron, 1985; Cameron et al., 1985; Cameron, 1986; Cameron and Jones, 1987). This progress report summaries recent work on vascular plant fossils from the Blomidon and Scots Bay formations (Fig. 2).

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[1] Funded by a Natural Sciences and Engineering Research Council general grant to Acadia University

[2] Department of Geology, Acadia University, Wolfville, Nova Scotia B0P 1X0

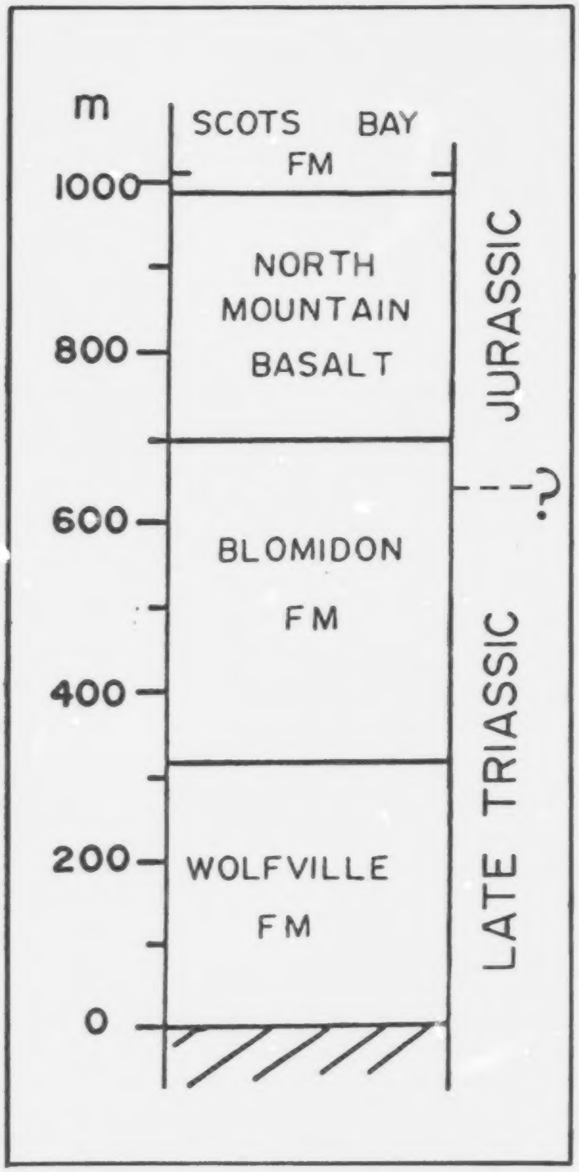

Figure 2. Generalized stratigraphic column for the lower Mesozoic rocks of the Annapolis Valley and North Mountain region of Nova Scotia. Plant fossils are now known from the lower and upper Blomidon and the Scots Bay formations.

LYCOPSIDS

Megaspores have been recovered for the first time from lower Blomidon Formation exposures near Blomidon and Rossway (Figs. 1 and 2). Because of their large size and prominent trilete mark, they are assigned to the form genus *Triletes* (Fig. 3e) (Stewart, 1983). They average 1.4 mm and range from 0.8 - 1.7 mm in diameter, have a smooth proximal surface and appear to have an equatorial flange (Fig. 3e). These megaspores probably represent the former presence of heterosporous lycopods in a desert-like climate (Ash, 1986), especially because of their association with the playa lake conchostracan *Cyzicus ovata* (Cameron and Jones, 1987) and salt crystal molds.

FERNS

Rare and poorly preserved ferns from the upper Blomidon Formation exposure at Central Clarence (Figs. 1 and 2) have been obtained for study. Several fern types, as well as other plant fossils, have been recognized so far (see Fig. 3a-b and next section below). We agree with the identification of *Cladophlebis* (Fig. 3a-b) by T. Delevoryas (Klein, 1962). The venation of most of these ferns is incompletely preserved, making preliminary identification uncertain.

Another fern, silicified in chert, was collected from the Central Broad Cove exposure of the Scots Bay Formation by Robert Grantham and Tracy Webb. We have identified it as *Clathropteris* (Fig. 3c). This is a worldwide, but uncommon, palmate fern that is characteristic of the Late Triassic to Early Jurassic (Bock, 1969). It is easily identified by its ladder-like venation produced by the primary and secondary branch veins. Tertiary veins and marginal details of the pinna are obscured.

?CYCADOPHYTES

A fragment of a possible bennettitalean leaf impression has been identified from the upper Blomidon material from Central Clarence. The specimen, which is 4 cm wide and 14 cm long, has over

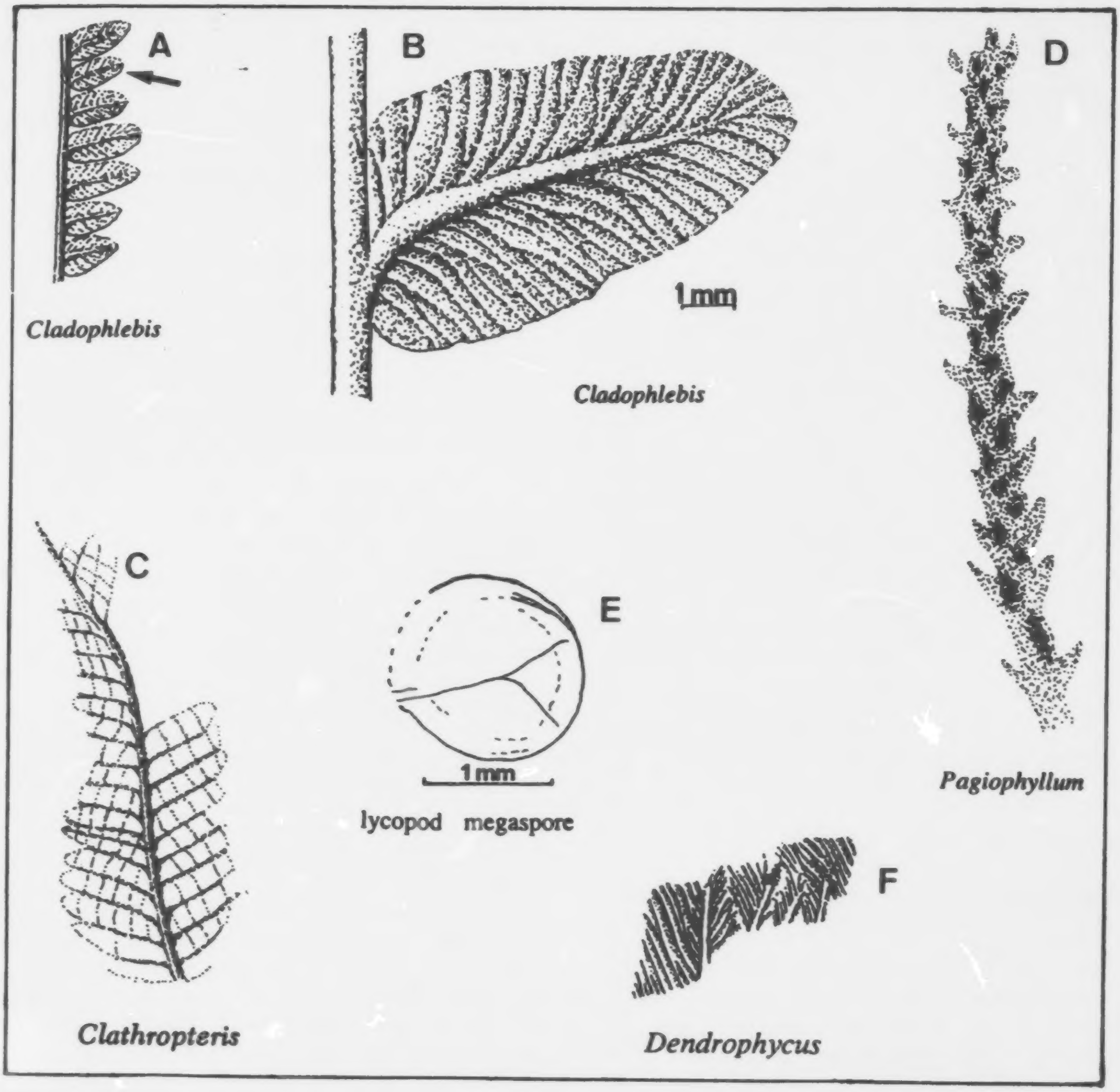
A
Cladophlebis
B
1mm
Cladophlebis
D
Pagiophyllum
C
Clathropteris
E
1mm
lycopod megaspore
F
Dendrophycus

Figure 3. Representative early Mesozoic plant fossils from the Fundy Group of southwestern Nova Scotia: (a) broken pinna of a Cladophlebis from the upper Blomidon Formation at Central Clarence; (b) enlarged view of a pinnule in A (arrow) showing poorly preserved venation; (c) incompletely preserved leaf of Clathropteris from the Scots Bay Formation at Central Broad Cove; (d) sterile twig of Pagiophyllum from the Scots Bay Formation at Lime Cove preserved in negative relief (dark spots represent tapering holes formed by weathered silicified leaves visible from the inside out); (e) lycopsid megascore Triletes from the lower Blomidon Formation at Blomidon; (f) rillmark-like pseudofossil Dendrophycus from upper Blomidon drill core near North Kingston. Drawings are natural scale except b and e (see bar scales); all but e are by Luc Daigle.

100 veins and resembles the large leafof *Eoginkgoites gigantea* Bock.

CONIFERS

Silicified leafy twigs resembling the vegetative features of *Araucaria* have been found in a large chert nodule from the Scots Bay Formation at Lime Cove (Fig. 1). The branches are covered with spirally arranged, broad and elongate, triangular leaves (Fig. 3d) that characterize the conifer foliage form genus *Pagiophyllum* (Taylor, 1981). No diagnostic reproductive structures have been recognized yet.

The jasperoid nodules of the Scots Bay Formation are cored by uncompacted fossils, possibly conifer wood, ranging from small twigs up to tree trunks. Some exhibit branching and the pith cavities are sometimes hollow. Often, the pith cavities are sediment-filled or lined with agate and(or) quartz crystals. Amethyst commonly occurs in these spaces and cavities associated with silicified stromatolites surrounding the wood.

PSEUDOFOSSILS

Dendrophycus occurs in the upper Blomidon Formation at 99 m depth in diamond-drill core GAV 77-1, which was drilled near North Kingston by Getty Mines Ltd. (Cameron and Jong, 1985), and in lower Blomidon Formation coastal outcrops near Delhaven (Fig. 1). This complexly branching structure (Fig. 3f) appears to be a plant fossil, but also closely resembles convex-up, rill-like structures. It is presumably inorganic in origin.

ACKNOWLEDGMENTS

We thank Robert Grantham of the Nova Scotia Museum and George R. Stevens of Acadia University for the loan of specimens. Mr. Luc Daigle drew most of the illustrations in Figure 3. Marcos Abreu, Heather Cameron and Charina Cameron provided able assistance in the field.

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GEO-DATABASE INTEGRATION IN THE ANTIGONISH HIGHLANDS, NOVA SCOTIA

T. Webster[1] and M. S. Akhavi[1]

INTRODUCTION

The purpose of this project was to create a multilayer geo-database over the Antigonish Highlands consisting of satellite Thematic Mapper (TM) imagery, airborne vertical gradient magnetic and radiometric imagery, digitized bedrock and surficial geology maps, digitized lineaments and mineral occurrences, and radar images.

METHODOLOGY

The process involved transfer of data from both mini- and microcomputer based image analysis and geographic information systems (GIS) with the final database residing on the microcomputer-based TYDAC, SPANS GIS. The minicomputer-based ESRI, ARC/INFO GIS was used for manual digitization of conventional data prior to being transferred into the SPANS microcomputer. The minicomputer-based DIPIX, ARIES II image analysis system was used to register the image data (satellite and geophysics) to a common projection system, as well as to enhance and classify the digital data. The microcomputer-based PCI, EASI/PACE image analysis system was used for enhancements, classifications and ink-jet plotting of the imagery. The final database residing on the SPANS system was used in various overlay modelling techniques to produce interpretive geological maps.

OBSERVATIONS

The Antigonish Highlands comprise rocks ranging from Precambrian to Devonian/Carboniferous in age; the stratigraphy of the Highlands is outlined by Murphy et al. (1982) and Murphy (1984).

The landsat TM images were useful in depicting various lithostratigraphic units within the Highlands, especially in the north-central region where topography is more rugged. Principal component analysis of TM bands 7, 5 and 4 revealed an interesting structural relationship between the Arisaig and Georgeville Groups and the boundary between the Hollow and Browns Mountain Faults. The Arisaig Group appears to have a dense coniferous vegetative cover and therefore is distinguishable from the Georgeville Group which is predominantly covered by deciduous species. The vegetative cover over Arisaig Group sections forms a 'bow-tie' shaped shear zone truncated by the two major faults in the area.

The geophysical data also identified the Highlands in comparison to the adjacent Carboniferous basin rock. These images dramatically highlighted contact relationships and defined various surface and subsurface structures. For example, magnetic data revealed the Hollow and Browns Mountain Faults, as well as the fault contact of the Chisholm Brook Formation of the Georgeville Group with the Devonian/Carboniferous rocks near Cape George. The data revealed anomalous zones within the Carboniferous basin itself, for example it is indicated that a strong positive magnetic gradient occurs directly under Antigonish Harbour. This may correspond to a structure that influenced the formation and orientation of the harbour itself.

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[1] Nova Scotia College of Geographic Sciences, Lawrencetown, Nova Scotia B0S 1M0

The radiometric data generally give a low response in various regions of the Highlands except in areas of faulting where a higher response is detectable. This is possibly due to alteration associated with the fault zone. The combination of lows and highs within the radiometric data makes it possible to identify and delineate the highlands from adjacent areas. There appears to be a difference in the radiometric signature within the Georgeville Group's formations north and south of Hollow Fault. The Chisholm Brook Formation in the north portion of the Highlands has a lower radioelement response (except for potassium) than the James River and Maple Ridge formations in the central Highlands south of Hollow Fault.

C-Band radar images highlighted the unconformable contact between the Georgeville and Arisaig Groups and the younger Carboniferous basin rocks. The 'bow-tie' is not easily detectable on these images, however a lineament was identified that may result from the contact between the James River and Keppoch formations.

CONCLUSIONS

The process of integrating conventional geological data, airborne digital geophysical imagery and Landsat TM multispectral imagery into a single co-registered database provided an opportunity to detect various geological, stratigraphic and structural features. The modelling ability of microcomputer-based geographic information systems, assisted by digital image processing, was essential for the preparation of a number of interpretive geological maps and prints. The resultant data are useful for a better understanding of the geological framework within the Antigonish Highlands.

Additional information pertaining to this topic will be displayed in our poster at the Open House and is outlined in a co-operative project report completed by Webster (1988).

ACKNOWLEDGMENTS

This project was partially supported by the Geological Survey of Canada; technical assistance and expertise of Dr. Bonham-Carter in the data transfer process is very much appreciated.

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SUMMARY OF THE GEOLOGY OF THE EASTERN COBEQUID HIGHLANDS[1]

J. B. Murphy[2], G. Pe-Piper[3], R. D. Nance[4], D. S. Turner[3] and B. Miller[4]

The eastern Cobequid Highlands are underlain by Precambrian to Carboniferous rocks. The oldest rocks have been assigned to the Bass River and Mount Thom Complexes (Donohoe, 1983). These complexes occupy a narrow belt between the Londonderry and Rockland Brook faults and consist of a gnessic basement (e.g. Great Village River Gneiss) and two greenschist facies sequences, the metasedimentary Gamble Brook Formation and the metavolcanic Folly River Formation (Donohoe and Wallace, 1985; Murphy et al., 1988). The contact between the Great Village River Gneiss and the Gamble Brook Formation is defined by a ductile shear zone and is associated with younger, syntectonic granite gneisses. These features obscure the original relationship between these units. At present an unconformity is the preferred interpretation although this cannot be demonstrated in the field. The Folly River Formation unconformably overlies the Gamble Brook Formation.

The above units are currently being dated using the U-Pb method by R. Doig of McGill University. A minimum age of 630 Ma for the Great Village River Gneiss and Gamble Brook Formation is given by the age of the granite gneisses that intrude them (Gaudette et al., 1984). A minimum age for the Mount Thom Complex is not available although according to Gaudette et al. (1984) the Rb-Sr whole-rock age of 934 ± 82 Ma firmly establishes its antiquity. The depositional age of the Gamble Brook Formation is unknown although it is traditionally correlated with the lithologically similar Green Head Group of New Brunswick (Donohoe, 1983), which contains stromatolites of probable mid Rhiphean age (Hoffman, 1974). A maximum age for the Folly River Formation is obtained from crosscutting relationships with the penetrative fabric associated with the 630 Ma old ductile shear zone. A minimum age is provided by the Debert Pluton which post-tectonically intrudes the Folly River Formation and yields a 596 ± 70 Ma age (Donohoe et al., 1986; Rb-Sr whole rock).

The mafic rocks of the Folly River Formation are differentiated, within-plate continental tholeiites and are attributed to limited rifting (Pe-Piper and Murphy, in press). They are similar to the Clydesdale Formation in the Antigonish Highlands and were probably formed in a similar environment (i.e. a rift within a Late Precambrian volcanic arc). Late Precambrian granitoid rocks also display volcanic arc affinities.

Three major periods of deformation within the complex are considered to be of Precambrian age (Donohoe and Wallace, 1985; Cullen, 1984; Nance and Murphy, in press). The earliest (D_1) affects only the gneiss and demonstrates the existence of basement-

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[1] Funded by Geological Survey of Canada under the Canada - Nova Scotia Mineral Development Agreement

[2] St. Francis Xavier University, Antigonish, Nova Scotia
[3] St. Mary's University, Halifax, Nova Scotia
[4] Ohio University, Athens, Ohio, U.S.A.

cover relations. The second additionally affects the Gamble Brook Formation and records polyphase ductile shear (D_2a/D_2b) attributed to sinistral transtension at ≈630 Ma. Locally sheeted, late-kinematic mafic dykes suggest limited crustal extension and may herald development of basinal conditions in the Folly River Formation. The third deformation (D_3a/D_3b) records dextral transpression and northwest-directed thrusting in the Folly River Formation. D_3 is tentatively attributed to basin closure during formation of the latest Precambrian Jeffers Group. Regional considerations suggest that D_2 and D_3 kinematics may be related to development and destruction (respectively) of a Late Precambrian volcanic arc rift.

Cambrian and Ordovician rocks are not represented in the eastern Cobequid Highlands. Silurian and Lower Devonian rocks are dominated by fine grained, fossiliferous siliciclastics and are correlated with the Arisaig Group in the Antigonish Highlands. Devono-Carboniferous rocks are dominated by bimodal igneous rocks (both volcanic and intrusive. In general Devono-Carboniferous magmatism is within-plate and rift related (Pe-Piper et al., in press). The entire area was affected by strike-slip related deformation of predominantly dextral sense. This produced positive flower structures (Miller et al., in preparation), en echelon overturned folds and thrusts. This deformation is attributed to movement along the Minas Geofracture associated with docking of the Meguma Terrane.

ACKNOWLEDGMENTS

We thank Fred Chandler for organizational support, and David Piper and Duncan Keppie for discussions. We wish to acknowledge the contribution of Howard Donohoe, Peter Wallace and Mike Cullen to the understanding of the geology of the Cobequid Highlands.

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THE FOURCHU GROUP AND ASSOCIATED PLUTONIC ROCKS OF SOUTHEASTERN CAPE BRETON ISLAND, NOVA SCOTIA[1]

S. M. Barr[2], *A. S. Macdonald*[2], *C. E. White*[2], *and N. A. Van Wagoner*[2]

INTRODUCTION AND PURPOSE

Remapping of the Fourchu Group (Weeks, 1954) and associated granitoid and pre-Middle Cambrian rock units in southeastern Cape Breton Island was completed during the summer of 1988. This project was begun in 1987 (Barr et al., 1987), although related studies had been completed previously (McMullin, 1984; Barr and Setter, 1986; Thicke, 1987; Dennis, 1988; Sexton, 1988). The Fourchu Group is the most widespread unit in southeastern Cape Breton Island, occurring in five separate belts: Coxheath Hills, East Bay Hills, Sporting Mountain, Stirling, and Coastal (Fig. 1; Barr et al., 1987). Stratigraphy within the Fourchu Group was undetermined prior to the present study except in local areas (Murphy, 1977; Keppie et al., 1979; Donohoe, 1981; Macdonald, 1983). An important associated problem is the relationship between rocks assigned to the Fourchu Group by Weeks (1954) and the Lower Cambrian units which he termed the Morrison River, MacCodrum, and Canoe Brook formations, interpreted to conformably overlie the Fourchu Group. Smith (1978) attempted to resolve this problem in the northeastern part of the Stirling belt by revising the stratigraphy and introducing the terms Giant Lake Complex and Kelvin Glen Group.

The goals of the present project include:

(1) determination of the stratigraphic/lithologic divisions within the Fourchu Group in the Coxheath Hills, East Bay Hills, Sporting Mountain, Stirling, and Coastal belts, and comparison of these five areas in terms of stratigraphy and tectonic environment;

(2) resolution of the relation between the Fourchu Group and pre-Middle Cambrian units in the Stirling and Coastal belts;

(3) interpretation of the tectonic environment of the volcano-sedimentary rocks by means of detailed physical volcanologic studies in selected representative areas and whole-rock geochemistry; and

(4) description of the plutonic rocks in southeastern Cape Breton Island and determination of their relation to the volcano-sedimentary units.

These goals are important because of the economic potential of these rock units. The Fourchu Group and associated granitoid rocks have been the focus for mineral exploration and significant deposits are known to be present (e.g. Cu-Mo-Au in the Coxheath Hills belt, Zn-Pb-Cu-Ag-Au in the Stirling belt, and Cu-Mo-Zn-Bi-Ag in the Gabarus Bay area of the Coastal belt). Better definition of rock units

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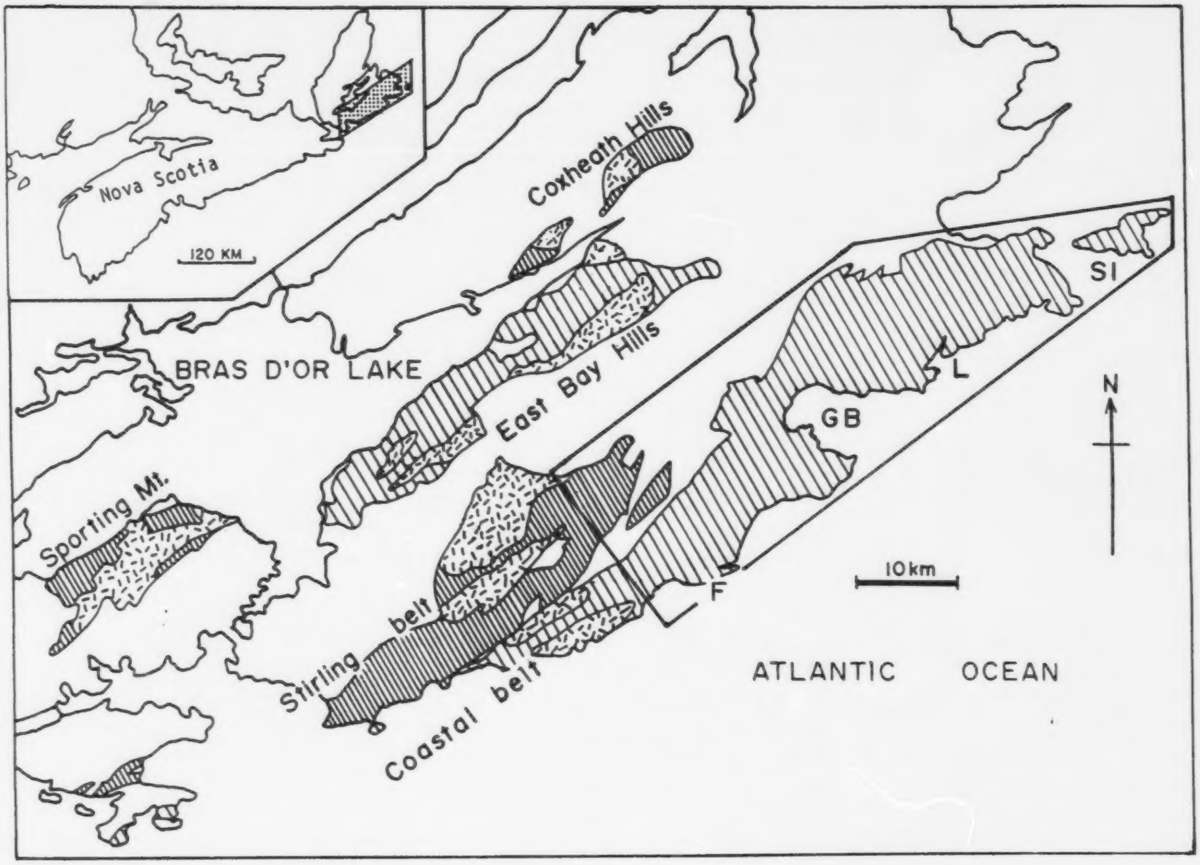

Figure 1. Distribution of the Fourchu Group (diagonal lines) and associated Late Hadrynian-Early Cambrian plutonic rocks (dash pattern) in southeastern Cape Breton Island. The area mapped in 1988 is outlined in black. Other areas were mapped previously as described in the text. The Fourchu Group in the Coastal belt and East Bay Hills is indicated by widely-spaced diagonal lines and in the Coxheath Hills, East Bay Hills, and Stirling belt by narrowly-spaced diagonal lines. Localities mentioned in the text are Scatari Island (SI), Louisbourg (L), Gabarus Bay (GB), and Fourchu (F).

and tectonic environment will help to further define mineral exploration targets.

PROGRESS REPORT

During the summer of 1987, geological mapping of the East Bay Hills was completed, tying into earlier work in the Sporting Mountain area (Sexton, 1988), the East Bay Hills (McMullin, 1984; Thicke, 1987) and the Coxheath Hills (Barr and Setter, 1986; Thicke, 1987). Mapping was also done in the southwestern parts of the Stirling and Coastal belts (Fig. 1). Preliminary descriptions of the rock units were presented by Barr et al. (1987) and the maps were compiled and published in an open file report (Barr et al., 1988).

During the summer of 1988, mapping was completed in the Stirling and Coastal belts. In addition, detailed studies of the stratigraphy and volcanology were completed in several key areas to interpret the depositional environment of representative units.

Detailed studies of the petrography, geochemistry, and volcanology of the units are continuing, and the results, together with compilation maps of the entire area, will be incorporated in a final report by April, 1989.

RESULTS OF 1988 MAPPING

In the Fourchu area (Fig. 1), a series of tuffaceous units which generally trend east-northeast and young westward were mapped. They include lithic tuff, crystal-lithic tuff, and lithic-crystal tuff, mainly of intermediate and felsic composition. However, a broad mafic unit consisting of lithic and crystal tuff with some mafic flows occurs within the sequence. These units appear to be a continuation of many of the units in the southwestern part of the Coastal belt (Barr et al., 1988).

Some of the intermediate to felsic lithic tuff units can be traced to the northeast, to an area south and southwest of Gabarus Bay (Fig. 1). However, in general this area is dominated by widespread units of massive to amygdaloidal basalt and andesite, mudflow breccia, and mafic lithic tuff, with minor wacke. A distinctive felsic quartz-feldspar crystal tuff unit can be traced to the north of Gabarus Bay as far as Louisbourg. However, most of the units west and northwest of Gabarus Bay are distinctive dark-coloured dacitic lapilli tuffs which do not appear to be present south of Gabarus Bay.

Northeast of Louisbourg, the section consists mainly of green to grey siliceous dacitic lithic tuffs with common laminated chert horizons, intruded by voluminous feldspar porphyry.

However, at the northeastern end of the Coastal belt and on Scatari Island, a heterogeneous but distinctive assemblage of units is present. These units can be traced along much of the western part of the map area, adjacent to the Fourchu Group, generally as far as the Fourchu area. They include dominantly red and green volcanic breccia/conglomerate, locally interlayered with finer grained sedimentary rocks, brick-red porphyritic rhyolite, grey slate, quartzite, quartz-pebble conglomerate, and red to maroon arkosic sandstone and siltstone. These units are tentatively assigned to the latest Precambrian to early Cambrian. Previously, they were included in both the Fourchu Group and in overlying Lower Cambrian units, hence stratigraphic revision is required.

Granitoid units are rare in the map area and those present are of limited extent. Gabbroic rocks are more abundant and form several small plutons.

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BASIN CONFIGURATION AND SEDIMENTARY FACIES OF THE HORTON GROUP, CAPE BRETON ISLAND[1]

A. P. Hamblin[2]

INTRODUCTION AND OBJECTIVES

The non-marine Horton Group was deposited in post-Acadian, fault-bound extensional basins in western and northern Cape Breton Island and on mainland Nova Scotia. This study employs a sedimentological/stratigraphic approach to help establish the complex relationships between tectonic setting, facies geometry and resource potential of the Horton Group on Cape Breton Island. A summary of preliminary ideas and previous work was included in Hamblin (1988). A total of 24 000 m of strata were measured in 66 outcrop sections in the study area and lithological data from 8 onshore and 2 offshore exploration wells have been incorporated into the study (Fig. 1).

DEPOSITIONAL BASINS

Numerous topographically high basement blocks, which separate low-lying Horton Group outcrop areas, have led to the misconception that the Horton Group was deposited in many small sub-basins. Structural observations, contact relations, paleocurrent data and facies distributions from this study refute that concept. All structural features preserved in outcrop and core were post-depositional (i.e. Alleghenian). Some basement blocks were not positive features during Horton Group deposition, whereas others clearly represent the approximate location of basin margins during Horton Group deposition.

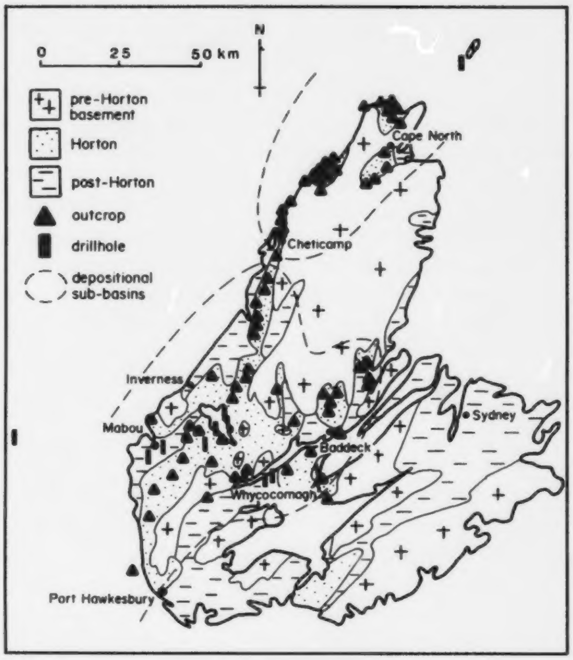

Figure 1. Simplified geological map of Cape Breton Island showing measured section locations.

The presence of coarse, immature reddened sediments near some basement blocks and distinct facies changes over short vertical and lateral distances indicate that most syn-sedimentary basin margins were fault-bounded. Facies distributions, paleocurrents and

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grain sizes show that Horton deposition in the study area occurred in only two large, fault-bound extensional sub-basins (northern, and western Cape Breton Island) with approximate dimensions of 100 x 40 km (Fig. 1). These sub-basins may represent half-grabens arranged en echelon with opposite polarity of asymmetry, as indicated by paleocurrent orientation. However, they underwent similar overall tectonic and depositional histories, implying that they were part of a larger unit of tectonic subsidence, analogous to the segments of a rift system (Gibbs, 1984; Frostick and Reid, 1987).

The tripartite stratigraphic scheme of the literature (Craignish, Strathlorne and Ainslie formations; Fig. 2) can be recognized in both fault-bound sub-basins. These lithologically defined units are probably diachronous megafacies which represent tectonically-controlled depositional settings arranged through time and space. The stratigraphic position and paleogeographic location of each outcrop determines the characteristics observed. The three megafacies can be further subdivided into 10 facies assemblages which occur in both sub-basins (Fig. 2).

HORTON GROUP FACIES ASSEMBLAGES

CRAIGNISH FORMATION

The basal Craignish megafacies represents a long initial phase of alluvial fan and braidplain sedimentation in a broad, slowly-subsiding basin and includes three facies assemblages: (1) Grey-green, coarse sandstone to conglomerate in sharp-based fining-upward beds with crossbedding and silty interbeds (braided fluvial environment near basin centres); (2) Red-orange, coarse sandstone to conglomerate with crossbedding, red silty interbeds, roots, desiccation cracks and calcrete zones (alluvial fan and braidplain environments near basin margins); and (3) Red siltstone to fine sandstone with roots, calcrete and desiccation cracks (alluvial mudflat or playa environments near basin centre).

STRATHLORNE FORMATION

The medial Strathlorne megafacies represents a period of maximum subsidence with dominantly lacustrine deposition in fault-bound sub-basins and includes four facies assemblages: (1) Dark grey burrowed mudstone with thin, rippled, very fine sandstone interbeds and pelleted or stromatolitic limestone (low energy, open lacustrine environment); (2) Grey-green, very fine to fine sandstone with horizontal lamination and hummocky cross-stratification (nearshore/shoreline progradation into lacustrine basins); (3) Red siltstone to fine sandstone with roots and calcrete zones (low energy mudflats associated with lacustrine shorelines); and (4) Grey-green medium sandstone and boulder conglomerate with crossbedding in sharp-based fining-upward beds (high energy, fault margin fan deltas).

AINSLIE FORMATION

The upper Ainslie megafacies represents a final period of decreased subsidence and consequent infill of the lacustrine sub-basins and includes three facies assemblages: (1) Red or grey, pebbly coarse sandstone to conglomerate in sharp-based fining-upward beds with crossbedding and imbrication (alluvial fan and braidplain environments near fault margins); (2) Red, fine to coarse sandstone in sharp-based fining-upward beds with crossbedding, rippling, roots and calcrete zones (high sinuosity fluvial environments near fault margins); and (3) Grey-green, very fine to fine sandstone in sharp-based fining-upward lenses with rippling and siltstone interbeds (high sinuosity fluvial environments near basin centres).

MEGAFACIES	FACIES ASSEMBLAGES	POSITION
AINSLIE	red/grey pebbly css-cgl (alluvial fan/braidplain)	↑basin margin
	red fss-css &si (fluvial)	
	grey/green vfss-fss&si (high sinuosity fluvial)	↓basin centre
STRATHLORNE	dark grey burrowed mudstone (open lacustrine)	↑basin centre
	grey/green vf ss-fss (nearshore/shoreline)	
	red si-fss (shoreline/mudflat)	
	grey/green mss-bldr cgl (fan delta)	↓basin margin
CRAIGNISH	grey/green css-cgl (braidplain)	↑basin centre
	brick red si-fss (mudflat/playa)	
	red/orange css-cgl (alluvial fan/braidplain)	↓basin margin

Figure 2. Horton Group facies assemblages. Megafacies are equivalent to formations of the Horton Group and are placed in stratigraphic order. Facies assemblages are arranged according to depositional position in basins.

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GEOLOGY OF THE JUBILEE ZINC-LEAD DEPOSIT, VICTORIA COUNTY, CAPE BRETON ISLAND, NOVA SCOTIA[1]

F. J. Hein[2], M. C. Graves[3] and A. Ruffman[4]

The Jubilee zinc-lead deposit (lat. 45° 49′ N, long. 60° 57′30" W) occurs near Little Narrows on Cape Breton Island. Over an intermittent exploration history of 50 years, 2 adits and 115 drillholes (total length drilled from 1974 to 1979 of 12 131.9 m) have outlined a mineralized zone of at least 500 000 tonnes in excess of 6% zinc and lead occurring in limestone, particularly where it is brecciated. The limestone breccia is better developed and thicker in a narrow zone parallel to the Jubilee Fault.

Twenty-six cores were examined in detail in this study and the main lithologies include, in ascending stratigraphic order, green and red conglomerate, limestone, limestone breccia, interbedded limestone and evaporite, and capped by a thick evaporite. The thickened carbonate section is adequately accounted for by deposition on the downthrown side of growth faults which were active during deposition of the Windsor Group and possibly the upper Horton Group.

It is proposed that fluids venting at points along the growth faults provided nutrient loci which concentrated thicker accumulations of biogenic carbonate. As carbonate deposition continued, positions along the growth faults were continued sites of preferred carbonate production and synchronous and(or) later brecciation through both mechanical granulation and dissolution by venting fluids. Liquid hydrocarbon migration occurred at least in part after brecciation to fill porosity and possibly as methane early in the history, providing nutrients for the carbonate-forming biota. Mineralizing fluids deposited sphalerite and galena followed by barite and calcite into hydrocarbon-filled pores. After initial carbonate sedimentation and subsequent growth fault activation, the deposit was a site of not only focused flow from below along the growth fault itself, but also of discharge of fluids from the Horton Group aquifer along the faces of the growth fault.

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The growth fault setting over thick Horton Group clastic basement opens much more of the Horton/Windsor surface for potential mineralization. If the same structural and sedimentological environment that is responsible for the localization of sedimentary exhalative vent fluids can assist in providing localization of benthic, carbonate-producing biota, identification of this sedimentological environment is fundamental in successful exploration for deposits of this type.

APATITE FISSION TRACK ANALYSIS OF THE THERMAL EFFECTS OF RIFTING ON THE ONSHORE NOVA SCOTIAN MARGIN: PRELIMINARY RESULTS OF NSDME DRILLHOLE D1[1]

C. Ravenhurst[2,3]*, Marcos Zentilli*[2] *and A. K. Chatterjee*

INTRODUCTION

Fission track dates and track-length measurements have been performed on apatites from deep drillhole NSDME D1 near Digby, Nova Scotia. The apatites are from granodiorite of the South Mountain Batholith which has been sampled in the core to a depth of 1437 m. Apatite fission track analysis is a new technology that gives the date that a rock cooled below a temperature of about 100°C (depth of about 3 km, at normal geothermal gradients). The analysis also provides information (track length data) on the thermal history of the rock (burial, metamorphism, uplift, erosion) in the temperature range 120-65°C. Apatite fission track analysis has increasing applications in the hydrocarbon and minerals industries and has also been used to elucidate complex uplift/ thermal histories of rifted continental margins (Moore et al., 1986).

The Atlantic margin of Nova Scotia is a rifted margin of extended continental crust and subcrustal lithosphere adjoining oceanic crust. The formation of the offshore sedimentary basin since the Jurassic has been modelled by Beaumont et al. (1982) who deduced the amount of extension from observations of crustal thickness and determined the subsidence history from offshore wells and seismic data. The fission track study gives time/temperature restrictions to the above model and others.

The region was affected by the Devonian Acadian Orogeny and by a pervasive thermal event, associated with regional shearing and fluid migration, in the Late Carboniferous (Zentilli and Reynolds, 1985; Ravenhurst, 1987; Reynolds et al., 1987, Muecke et al., 1988). Potassium feldspars in the plutons of southwestern Nova Scotia record an episode of argon loss at 220-230 Ma, a time coinciding with the age of mafic dikes in Shelburne and elsewhere in southwestern Nova Scotia. Extensive basalt extrusion took place in rift basins such as the Fundy Basin at 205-190 Ma (Hayatsu, 1979; Sutter and Smith, 1979), after which the locus of rifting shifted to the east, where the Scotian Basin developed. An erosional unconformity is recorded in the Scotian Basin in the Lower Jurassic (Given, 1977). Apatite fission track ages from the granitoids of southern Nova Scotia cluster at about 180 Ma, probably representing the time of final cooling of the crystalline rocks under 100°C (Elias, 1986; Grist, 1986; Reynolds et al., 1987).

METHODS

The fission track analyses were performed in the new regional Fission

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Track Research Facility at the Departments of Geology and Oceanography, Dalhousie University. The analytical technique and calibration have been described in Ravenhurst et al. (in press). The external detector method and (zeta) calibrations with apatite standards of known age are used. Irradiations were done at the McMaster University Nuclear Reactor. Temperature-time (T-t) paths computed for each sample were constrained by the measured age and track length data using modelling techniques developed by R. A. Donelick of Rensselaer Polytechnic Institute, Troy, N. Y. (Donelick et al., 1988).

SUMMARY OF NEW DATA

Apatite fission track analyses from central and southern Nova Scotia (onshore) yield Jurassic-Triassic dates and mean track lengths from 12.6 to 13.9 µm. The preliminary thermal models based on track length data suggest a cooling rate of 0.15-0.20°C/Ma over an approximate 180-30 Ma time interval computed by the model. Some samples were completely annealed before about 190 Ma, probably due to local effects of thermal or igneous activity related to rifting. In other areas the apatites were unaffected by this and record regular cooling from Permo-Carboniferous times. The deep hole samples are critical to distinguish between local thermal effects and those of regional significance. Further modelling may allow an estimate of uplift that might have been associated with early Cretaceous erosion and karstification in mainland Nova Scotia (Davies et al., 1984).

If the geothermal gradients were not strongly affected by thermal events, at least 3 km of erosion occurred over the entire Nova Scotian margin since the Permian. This overburden would have had significant effects on coalification and maturation of organic matter and thus influenced the fossil fuel potential of the region.

ACKNOWLEDGMENTS

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DEPOSITION OF THE LOWER THREE MEMBERS OF THE STELLARTON FORMATION[1]

L. C. Daigle[2]

During the summers of 1985 and 1986, mapping, section measuring and core logging were carried out in the western part of the Pictou coalfield as part of the requirement for a Masters degree in geology at Acadia University. The study was sponsored by the Geological Survey of Canada as part of the Stellarton Basin Project. The purpose of the study was to examine the lower three members of the Stellarton Formation: the Skinner Brook, the Westville, and the Plymouth members.

The Stellarton Formation was deposited in a graben which resulted from strike slip fault movement of the Cobequid and Hollow faults (Fig. 1; Yeo and Ruixiang 1987). Recent work (Naylor et al., 1986) supports Bell's (1940) interpretation of the Stellarton Formation as a fluvial-lacustrine sequence. The strata are characterized by rapid facies changes.

The lowermost unit, the Skinner Brook Member, is composed of red to mottled red-grey sandstone, siltstone, pebble conglomerate and rare carbonaceous mudstone. Primary sedimentary features suggest this member accumulated as an alluvial-fluvial deposit on the margin of a lake. Rare plant remains, rooted horizons, and bioturbation indicate that the deposits were vegetated. The degree of reddening observed in outcrop decreases as the member grades laterally basinward into finer grained, grey deltaic deposits of the Westville Member. Several thin units of carbonaceous mudstone were mapped on and near Middle River. One of these units rests directly on red rooted Skinner Brook Member, is overlain by grey Westville Member and is stratigraphically equivalent to the early Westphalian C Acadia coal seam (Yeo et al., 1988). This carbonaceous mudstone has yet to be sampled for spore age dating. Comparable carbonaceous units were found to rest on rooted horizons in red sandstones which interfinger in outcrop with grey sandstones of the Westville Member. Spores from these carbonaceous zones indicate a Westphalian A to B age (Dolby, 1987).

The Westville Member is composed of well-sorted, fine grained, grey sandstone and mudstone and features such as very low angle cross bedding and distributary mouth bar slump structures indicate deposition in muddy deltas. These deltaic deposits grade laterally into open water deposits composed of oil shale and interlaminated siltstone and organic-rich mudstone. Coal seams directly overlie the delta deposits which likely formed good platforms for peat swamp development.

The Plymouth Member is composed of red sandstone, siltstone and mudstone. The strata contain siderite nodules and are locally bioturbated. Rooted horizons with overlying carbonaceous mudstones occur within the package.

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[1] Funded by the Geological Survey of Canada under the Canada - Nova Scotia Mineral Development Agreement

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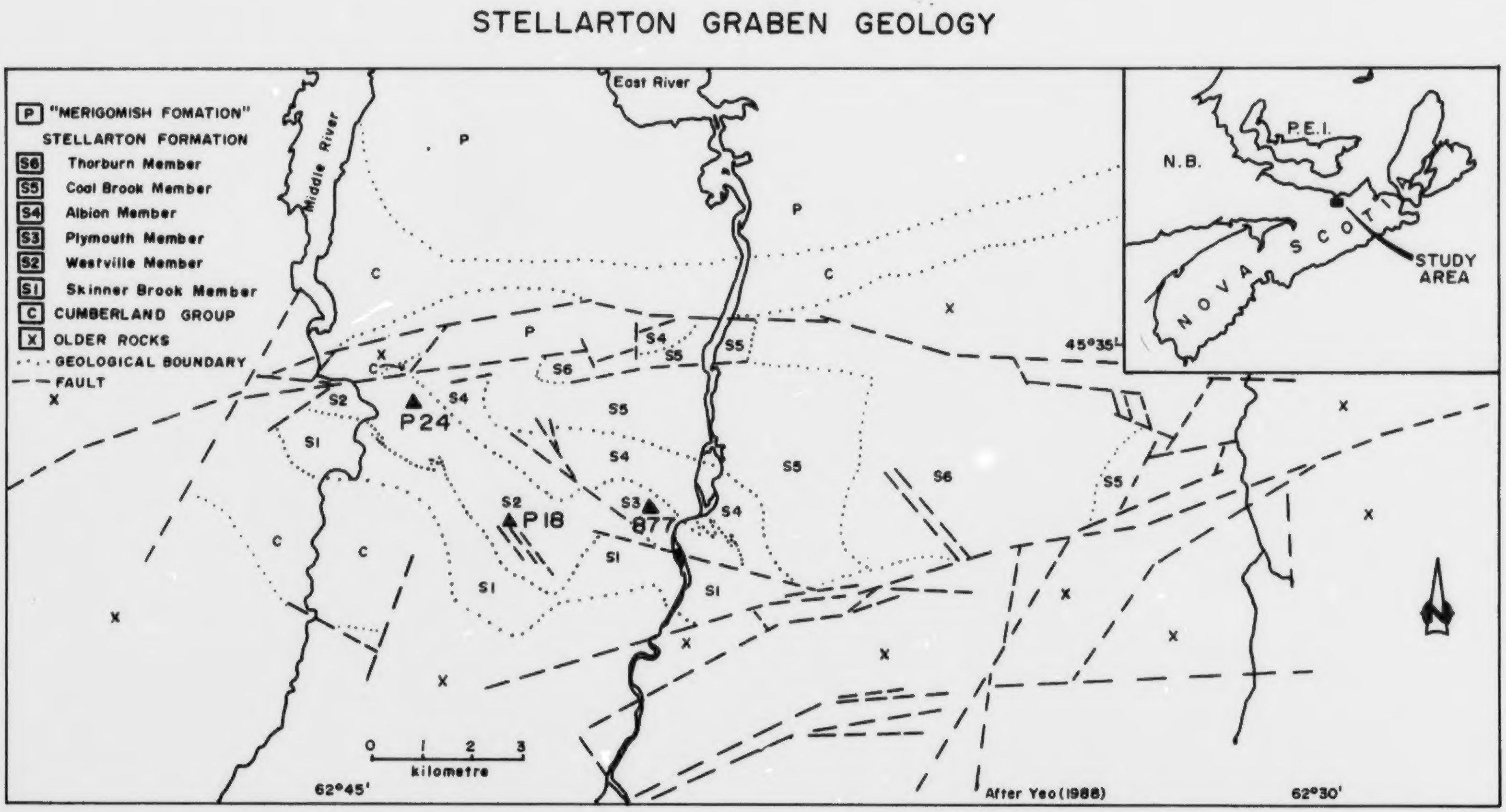
STELLARTON GRABEN GEOLOGY
P "MERIGOMISH FOMATION"
STELLARTON FORMATION
S6 Thorburn Member
S5 Coal Brook Member
S4 Albion Member
S3 Plymouth Member
S2 Westville Member
S1 Skinner Brook Member
C CUMBERLAND GROUP
X OLDER ROCKS
GEOLOGICAL BOUNDARY
FAULT
Middle River
East River
P24
P18
877
45°35'
62°45'
62°30'
0 1 2 3
kilometre
After Yeo (1988)
N.B.
P.E.I.
NOVA SCOTIA
STUDY AREA

Figure 1. Geology of the Stellarton Graben.

These features, and tabular sandstone beds interpreted as splay deposits, suggest that most of this member is a flood plain deposit. The Plymouth Member is observed in drill core to interfinger with the Albion Member of the upper Stellarton Formation. Interfingering of these members suggest that the carbonaceous mudstones of the Plymouth Member are laterally equivalent to coal seams within the Albion member. In drill core and in outcrop the Plymouth Member is observed to be in sharp contact with the top of the underlying Westville Member, but is nowhere observed in contact with the Skinner Brook Member.

Interpretation of the depositional environments of the three lower members of the Stellarton Formation is based on over 5000 m of stratigraphic section compiled from mapping and diamond drill core and from the many drill logs available in the Nova Scotia Department of Mines and Energy records. Figure 2 is a northwest-southeast cross-section based on three drill holes (P-24, P-18 and 877) and mapping (see Fig. 1 for bore hole locations). Correlation of some of the organic-rich mudstone sequences of the upper Skinner Brook Member with Westphalian C coal seams of the Westville Member suggests that many of the Westphalian A-B organic-rich mudstones lower in the Skinner Brook Member may pass laterally into coal seams not previously recognized in the Westville Member.

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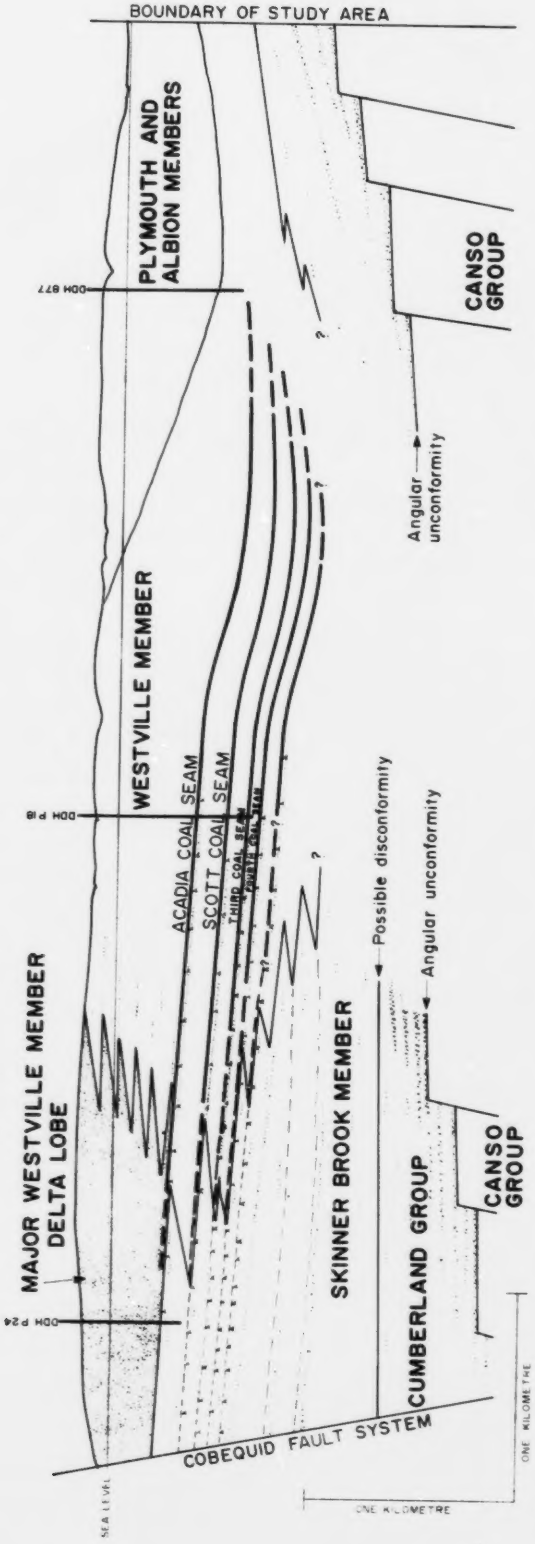
BOUNDARY OF STUDY AREA
PLYMOUTH AND ALBION MEMBERS
CANSO GROUP
DDH 877
Angular unconformity
WESTVILLE MEMBER
DDH P18
ACADIA COAL SEAM
SCOTT COAL SEAM
THIRD COAL SEAM
FOURTH COAL SEAM
?
Possible disconformity
Angular unconformity
MAJOR WESTVILLE MEMBER DELTA LOBE
SKINNER BROOK MEMBER
CUMBERLAND GROUP
CANSO GROUP
DDH P24
COBEQUID FAULT SYSTEM
SEA LEVEL
ONE KILOMETRE
ONE KILOMETRE

Figure 2. Northwest-southeast cross-section through part of the Stellarton Graben.

SULPHUR ISOTOPIC VARIATION IN MN-AS-AU-ZN-PB-BEARING STRATA: SEDIMENTATION AND DIAGENESIS IN AN ANOXIC BASIN IN CAMBRO-ORDOVICIAN FLYSCH OF THE MEGUMA GROUP, NOVA SCOTIA, CANADA[1]

A. L. Sangster[2], M. C. Graves[3], and M. Zentilli[4]

Sulphide δ34S profiles through Cambro-Ordovician flysch at the Caribou Au mine and Eastville Zn-Pb prospect show strong variation with host lithology which indicates dependence of sulphide deposition on sedimentary/diagenetic environment.

δ34S from the upper part of older Goldenville Fm greywacke (po) and vein quartz-Au ore (asp) are heavy (+17°/.. to +22°/..), indicating a host sediment source for vein S. Overlying coticule-bearing beds (1-25% Mn) have δ34S values of 0 to -5°/.. reflecting normal biogenic fractionation of S at a redox boundary during Mn precipitation. In the basal C- and Fe-rich slates of the overlying Halifax Fm, δ34S return to heavy values (+19°/.. to +25°/..) for a stratigraphic interval of 30 m indicating a return of anoxia coinciding with high organic productivity in the overlying oxic ocean. Final destruction of basin stratification is indicated by a sharp drop in δ34S ratios to 0 to -5°/.. which persists for at least 100 m up into Halifax Fm black slate. The Eastville Zn-Pb prospect is in rocks deposited during the transition between strong positive and negative δ34S and may have been deposited from sedex-type basin brines related to events which resulted in ventilation of the basin.

The conspicuous correlation of δ34S with sedimentary/diagenetic processes within the basin constrains models for vein Au and stratabound Zn-Pb to accommodate a source of S from seawater sulphate.

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[1] Reprinted from Abstracts with Programs, Geological Society of America, v. 20, no. 7, 1988 Annual Meeting and Exposition, October 31 - November 3, 1988, Denver

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PALEOSUPERGENE WILLEMITE MINERALIZATION, KIRKMOUNT, SOUTHERN ANTIGONISH HIGHLANDS, NOVA SCOTIA[1]

A. L. Sangster[2]

Siderite/ankerite veins and breccias host Ba-Cu-Pb-Zn mineralization in both metamorphosed basement rocks and Carboniferous clastic sedimentary rocks in and adjacent to the Cobequid-Chedabucto fault zone (mid-Devonian to Jurassic movement). At Kirkmount, breccias containing Zn-siderite (to 2% Zn) and minor barite and native Ag, cut late-Precambrian chloritic argillite and wacke. The argillite contains up to 4% low-Fe sphalerite as bedding parallel accumulations and randomly disseminated, micron-scale grains. Millimetre to centimetre scale fractures cutting the mineralized sedimentary rocks contain supergene minerals that include willemite, Mn-calcite (to 12% Mn), and red fluorescent, Pb-calcite (to 7% Pb) to depths of at least 65 m below the present weathering surface.

Willemite occurs as white to cream, radial crystal growths on fracture walls and disseminated within the argillite. It contains 0.09 to 0.5% Mn and has bright green fluorescence at Mn contents above 0.1%.

A semi-arid climate favoring the formation of willemite contrasts strongly with the present humid, moderate rainfall climatic regime. The willemite and other secondary minerals are believed to have formed by the oxidation of primary Zn-siderite and sphalerite and redeposition within narrow fractures formed by movement on the Chedabucto fault. Climatic conditions favoring the formation of willemite existed from mid-Devonian to Triassic. Consideration of the age of the primary mineralization and timing of suitable climatic conditions suggests a possible Permo-Triassic age for the deposition of the willemite-bearing veins.

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[1] Reprinted from Abstracts with Programs, Geological Society of America, v. 19 no. 7, Annual Meeting, October 26-29, 1987, Phoenix, Arizona

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SULPHUR AND LEAD ISOTOPE STUDIES ON TWO GRENVILLE-TYPE, MARBLE-HOSTED ZINC OCCURRENCES, CAPE BRETON, NOVA SCOTIA[1]

A. L. Sangster[2], and R. I. Thorpe[2]

The Meat Cove and Lime Hill marble-hosted zinc deposits, Cape Breton, Nova Scotia are geologically and geochemically similar to some marble-hosted zinc deposits in the Grenville Supergroup (eg. Balmat, N.Y.; Salerno Lake, Ont.). All contain sphalerite with iron sulphide and very low Pb, Cu, Ag and Au. The host marbles are strongly dolomitic with locally abundant, siliceous interbeds resulting in variations of a calcite-dolomite-quartz-tremolite-diopside-forsterite metamorphic mineral assemblage. Serpentine is a common retrograde mineral, particularly in forsterite-bearing marble. The deposits in Grenville Supergroup rocks are of sedimentary exhalative origin.

Both sulphur and lead isotopic ratios support the thesis that the Cape Breton deposits are similar in origin and age to those in the Grenville Supergroup. The Cape Breton occurrences are enriched in heavy sulphur (Lime Hill +9.5 to +12.6°/..; Meat Cove +12.4 to +17.5°/..) as are the Grenville deposits (Balmat +11.5 to +17.5°/..; Salerno Lake +9.7 to +12.6°/..). This similarity supports a synsedimentary origin by precipitation from saline basin brines as has been proposed for the Balmat deposit. Lead isotopic ratios from Lime Hill (206/204-17.085,17.000; 207/204-15.567,15.562; 208/204-36.748,36.718) and Meat Cove(206/204-17.134; 207/204-15.502; 208/204-36.565) are similar to ratios reported for Balmat galena, suggesting similar ages and lead evolution histories. This conclusion supports the recent assignment of a Grenville age to rocks at Meat Cove. At Lime Hill, recent work indicates a correlation of the Lime Hill gneiss with the Precambrian Kelly's Mt. gneiss which underwent low pressure, high temperature metamorphism about 700 my ago. The Lime Hill Pb isotopic ratios indicate that the Kelly's Mountain equivalents at Lime Hill may correlate with the Grenville Supergroup; the Lime Hill gneisses were perhaps only minimally affected by Grenville metamorphism, and then remetamorphosed during latest Precambrian time.

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COMPLEX HYDROMORPHIC AND GLACIO-MECHANICAL GEOCHEMICAL DISPERSION, FRENCH ROAD AREA, CAPE BRETON, NOVA SCOTIA: A CASE HISTORY[1]

A. L. Sangster[2]

Numerous small, granite-related, Cu-Pb-Zn-Mo-Ag-Bi occurrences are found over a wide area in the French Road-Deep Cove area, 25 km south of Sydney, Nova Scotia. They are hosted by volcaniclastic rocks of the late Proterozoic Fourchu Group and quartzite and argillite of the lower to middle Cambrian Morrison River, MacCordrum, Canoe Brook, and Trout Brook formations. Mineralization-types include greisen, skarn, veins and joint/fracture coatings in hornfels. The countryside is generally covered by thin overburden and outcrop is sparse. The last Pleistocene ice flow (azimuth 035°) resulted in the formation of numerous drumlins in the area, some of which are bedrock cored.

Mineral exploration follow-up of unsourced, hydromorphic, base-metal geochemical anomalies outlined 'B' horizon soil anomalies on two drumlins. One anomaly, near MacIntyre lake, consists of anomalous Cu-Bi geochemistry both on the crest of the drumlin and in organic material at the southeast slope base. Initial interpretations assumed that the topographic feature was bedrock cored and that the organic-hosted geochemistry was hydromorphically dispersed from the adjacent topographic high. However, geophysical surveys defined a target under the east flank anomaly and under the southwest nose of the drumlin. All three targets were drilled. Cu-Bi-Zn mineralization was found in the vicinity of both geophysical targets. The hole drilled on the geochemical anomaly on the crest of the hill was abandoned in overburden at a depth of about 30 m.

The second anomaly, near MacDonald lake, consists of widespread anomalous 'B' horizon Pb geochemistry, with weak Zn, on the eastern flank of a large drumlin. Strong hydromorphic 'A' horizon Pb anomalies, with weaker Zn, are found in a flowing swamp along the southeastern base of the drumlin. Geophysical surveys defined no likely targets. A program of backhoe pitting and vertical profile sampling defined a strong Pb anomaly trending obliquely up the flank of the drumlin. The strength of the anomaly (2000 to 5000 ppm Pb), the abundance of angular hornfels float (to 60% in the sampled overburden), and an apparent source of hydromorphic geochemistry well up the drumlin flank resulted in an interpreted metal source in a bedrock core within the drumlin. A hole drilled on the south end of the anomaly at the base beside the drumlin defined joint/fracture controlled galena and sphalerite mineralization. A second hole, drilled on the geochemical anomaly part way up the flank of the hill encountered thick overburden and indicated that the Pb anomaly was a product of glacial dispersion which was probably not related to the drumlin-forming ice flow.

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[1] Extended Abstract: Paper published in the Proceedings volume, 8th Symposium on Prospecting in Areas of Glaciated Terrain; Canadian Institute of Mining and Metallurgy, August 28 - September 3, 1988, Halifax, Nova Scotia

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The significance of these results to mineral exploration follows:

(1) Interpretations involving a simple origin for geochemical anomalies on drumlins in southeastern Cape Breton Island, from sources directly up ice, are not necessarily valid. The indicated source for the MacIntyre Lake anomaly lies up ice immediately adjacent to the nose of the drumlin and reflects the simple case. The indicated source for the MacDonald Lake anomaly is beside the drumlin and is interpreted as a product of dispersion by a late ice movement over-riding an earlier formed drumlin. The fact that the MacDonald Lake drumlin axis (055°) is not parallel to other local drumlins (0° to 035°) may indicate its formation from ice flow around Blue Mountain.

(2) The magnitude of the Pb and Zn anomalies on the drumlin flank were significantly higher and lower respectively than bedrock Pb-Zn values encountered in drilling. This is believed to be a result of the wholesale erosion and transport of joint mineralized hornfels and deposition of the rock material on the drumlin flank with a relatively small amount of interstitial soil. The strong lead anomaly and suspected stronger original zinc anomaly resulted from the complete weathering of the pyrite-sphalerite-galena mineralization exposed on joint surfaces of rock fragments in the till. Much of the original Zn content of the till is thought to have been removed by leaching since deposition, leaving a weak residual Zn anomaly.

PROGRESS REPORT ON DATA INTEGRATION PROJECT: EASTERN SHORE, NOVA SCOTIA[1]

G. F. Bonham-Carter[2], D. F. Wright[2], J. R. Harris[3],
P. J. Rogers[4] and F. P. Agterberg[2]

This project involves building a multi-layer spatial database with a microcomputer-based geographic information system called SPANS, and using the database to examine interrelationships between map layers. The study area comprises two geographic areas: (1) areas covered by Meguma Group rocks and (2) the Antigonish Highlands area. Work on the Meguma Group part of this project is nearing completion and the Antigonish Highlands part will be completed during the 1988-89 winter.

In the Meguma Group, it has been demonstrated that the lake sediment geochemical data are a good predictor of known gold occurrences. A linear combination of lake sediment Au, As, Sb and W predicts all the major gold districts, with the possible exception of Forest Hill. A gold potential map based on lake geochemical data shows several prospective areas where no major gold mineralization has been reported (Wright et al., 1988).

A new method for modelling map layers using conditional probability has been employed to combine the geochemical signature for gold with information on distance to linear features (lineaments, contacts, fold axes) and rock types (Agterberg et al., in press). Each map layer is first transformed to a presence/absence form, producing a binary pattern. For each layer, a positive and negative weight is calculated using conditional probability expressions: positive weight applies when the binary pattern is present, negative weight when the pattern is absent. A 'unique conditions' map is generated, which breaks up the region into classes, each class having a unique set of overlapping conditions of the binary predictor maps. Finally, a probability map and an uncertainty map are generated; the former shows the posterior probability of gold occurrence per km^2, the latter depicts the variance of this probability estimate. Results from the Meguma Group show that the presence of the anomalous lake sediment geochemical signature is the most significant predictor of known gold mineralization, followed by proximity to anticlinal fold axes, proximity to the Goldenville - Halifax contact, proximity to the granite contact, and the presence of the Goldenville Formation (Bonham-Carter et al., 1988). Surprisingly, proximity to northwest-trending lineaments is not predictive of known gold occurrences in this area, in contrast to the results of Bonham-Carter et al. (1985) for a region farther west. This predictive method is particularly valuable for combining data where some map layers are incomplete. For example, although the lake sediment catchment basins covered about 60% of the study area, predictions of gold potential were possible outside the lake basins, but for these polygons the probability estimates have a higher variance, as shown in the uncertainty map.

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[1] Funded by Geological Survey of Canada under the Canada - Nova Scotia Mineral Development Agreement

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[3] Intera Technologies/Radarsat Office, Canada Centre for Remote Sensing, Ottawa

[4] Nova Scotia Department of Mines and Energy, Halifax, Nova Scotia

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AEROMAGNETIC TOTAL FIELD, GRADIOMETER, VLF SURVEY - COBEQUID HIGHLANDS, NOVA SCOTIA[1]

D. Teskey[2], E. Ready[2], P. Stone[2] and F. Kiss[2]

An aeromagnetic/gradiometer/VLF survey was flown in the Cobequid Highlands area of Nova Scotia under contract to the Geological Survey of Canada as a contribution to the Canada - Nova Scotia Mineral Development Agreement, 1984-89. The survey area is shown in Figure 1. The contract was awarded to Sander Geophysics Ltd. of Kanata, Ontario, and was flown in the period October 1986 to June 1987. The gradient field was measured by two cesium vapour magnetometers separated by 2 m and suspended 30 m below a helicopter. VLF total field and quadrature were also recorded using signals from Cutler, Maine, and Annapolis, Maryland. A mean elevation clearance of 150 m was maintained with a flight line speration of 300 m.

Survey products are 1:25 000 aeromagnetic total field and gradiometer contour maps and 1:50 000 colour interval maps. The VLF total field and quadrature are plotted in profile form on the back of the magnetic total field and gradiometer colour interval maps in such a way that they can be viewed together using a light table. The digital data can also be purchased from the Geophysical Data Centre, Geophysics Division, Geological Survey of Canada, 1 Observatory Crescent, Ottawa, Ontario, K1A 0Y3 (telephone 613-992-6438) for further processing and interpretation.

The total magnetic field represents the integrated effect of the magnetism of source rocks in the area, down to the Curie point depth at 20 km or more. The gradiometer data are much more sensitive to near-surface effects and, particularly in northern latitudes, the zero gradient contour

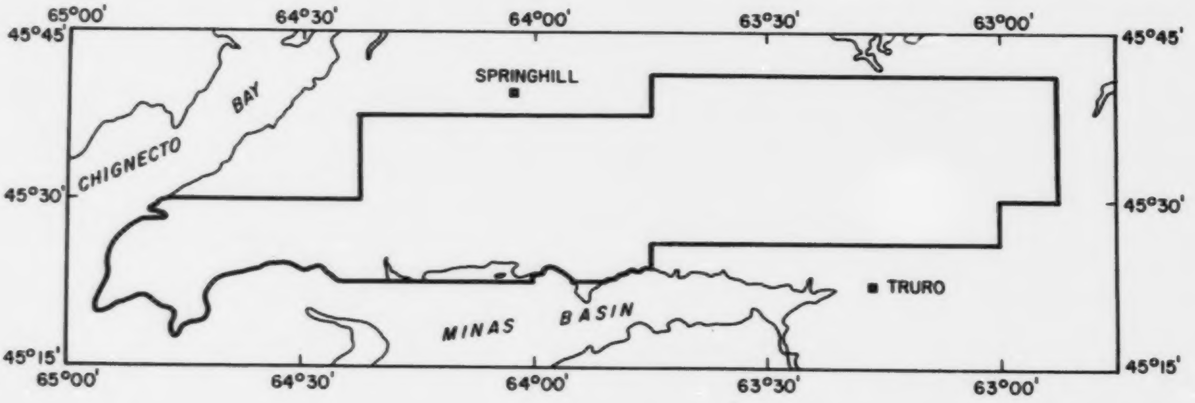

Figure 1. High resolution aeromagnetic total field/gradiometer/VLF survey area, 1986/87 - Cobequid Highlands, Nova Scotia.

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[1] Funded by Geological Survey of Canada under the Canada - Nova Scotia Mineral Development Agreement

[2] Geological Survey of Canada, 1 Observatory Crescent, Ottawa, Ontario K1A 0Y3

tends to outline surface contacts, although it may be slightly offset by the inclination of the magnetic field, remanent magnetization and the interference from nearby sources. The VLF signals are sensitive to near-surface conductors such as groundwater or graphite in faults, conductive minerals such as metallic sulphides, and cultural features.

A preliminary report on the geology of the eastern Cobequid Highlands has been published by Murphy et al. (1988a) along with a map at 1:50 000 scale (Murphy et al., 1988b). Examination of this map in conjunction with the aeromagnetic and gradiometer maps shows that the major fault system and contacts, such as the Cobequid Fault and the major unconformity, which separate the Cobequid Highlands from younger Carboniferous rocks to the south and north respectively, are particularly well delineated, as is the Rockland Brook Fault, which separates the Precambrian Bass River Complex in the southern portion of th Highlands from younger Paleozoic gabbro, diorite and granite to the north. Major contacts between the gabbro and granite can also be delineated approximately parallel to the major fault systems. Units such as the mafic volcanics of the Fountain Lake Group can be extended and better defined on the aeromagnetic maps, as can the smaller fault systems that are orthogonal to major contacts. The aeromagnetic and gradiometer data should be particularly useful for unravelling the complex, Precambrian Bass River Complex (Nance and Murphy, 1988) that lies between the Rockland Brook and Cobequid Faults.

Detailed study of these data sets should greatly contribute to understanding the geological structure of this area and thus help to define targets of potential economic significance.

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LITHOGEOCHEMICAL INDICATORS OF GOLD POTENTIAL IN THE EASTERN MEGUMA TERRANE OF NOVA SCOTIA: SECOND PROGRESS REPORT[1]

J. A. Kerswill[2]

The focus of this work is to document chemical and mineralogical features of host rocks to gold-bearing quartz veins in an effort to better establish useful indicators of gold potential. A related objective is to provide additional constraints in building a predictive genetic model for turbidite-hosted gold deposits.

During the 1986 and 1987 field seasons, more than 500 rock samples were collected from recently obtained drill core or underground exposures in seven gold districts, namely Beaver Dam, Caribou, Fifteen Mile Stream, Goldenville, Lake Catcha, Moose River and Tangier. In addition, more than 50 reference samples were collected from outcrops in areas several kilometres from known mineralization. Samples have been grouped into a large number of populations according to district, lithology, proximity to gold-bearing veins, apparent intensity of alteration, and their contents of iron sulphides, arsenopyrite, carbonate and gold. Manipulations to date on major, minor and trace element data have been directed toward evaluating differences among districts and rock types in terms of element concentrations and correlations among elements. A brief summary of field relationships and references pertinent to this study were presented in the initial progress report (Kerswill, 1987).

The best geochemical indicator of gold potential is gold itself. Sulphur and arsenic appear to be the only other elements that can be usefully correlated with gold. This reflects the common association between gold, pyrrhotite, pyrite and arsenopyrite. Ranges and average contents of gold, sulphur and arsenic, as well as interrelationships among the three elements, are significantly different in different rock types (slate, wacke and quartz veins) and from district to district. Although gold is positively correlated with both sulphur ($r = 0.48$) and arsenic ($r = 0.46$) in a composite population ($N = 291$) that includes all host rock and vein samples from all districts, these correlations can break down at the district level (Fig. 1). Both arsenic and sulphur are useful indicators for gold in some districts, as in Beaver Dam (Fig. 1). In other districts, as in Tangier, sulphur is much more reliable than arsenic as a guide to gold (Fig. 1). In some districts, neither sulphur nor arsenic are well correlated with gold. Although gold-rich samples are rarely poor in sulphur, gold-poor samples can be high in sulphur and(or) arsenic (Fig. 1). Numerous samples of black, pyrrhotite-rich but arsenopyrite-poor slate from a number of districts contain less than 10 ppb gold.

The K_2O/Na_2O ratio appears to be a

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[1] Funded by Geological Survey of Canada under the Canada - Nova Scotia Mineral Development Agreement

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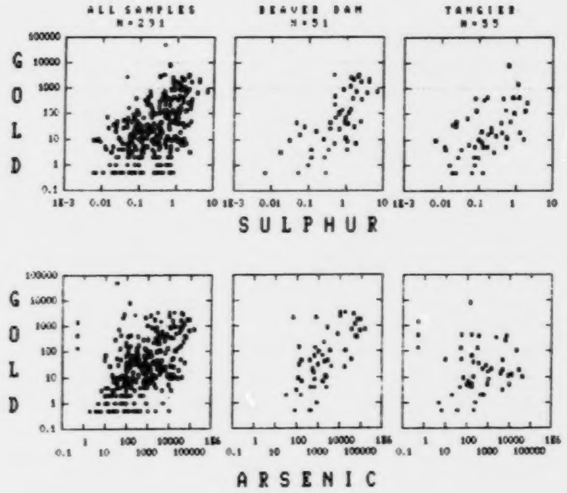

Figure 1. Gold versus sulphur, and gold vs arsenic scattergrams for, (1) a composite population (N = 291) including wacke, slate and quartz vein samples from known gold districts, (2) wacke, slate and quartz vein samples (N = 51) from Beaver Dam, and (3) wacke, slate and quartz vein samples (N = 55) from Tangier. Gold values in ppb, arsenic in ppm and sulphur in wt. %. All data were log transformed.

Correlation coefficients and levels of significance (in brackets) for each scattergram are as follows: (1) composite population, Au-S = 0.48 (0.00001), Au-As = 0.46 (0.00001), (2) Beaver Dam, Au-S = 0.68 (0.00001), Au-As = 0.63 (0.00001), and (3) Tangier, Au-S = 0.54 (0.00002), Au-As = -0.04 (0.39896). All data were log transformed prior to correlation analysis.

potentially useful indicator of gold-related hydrothermal alteration in both wacke and slate. Anomalously high values of this ratio occur in some, but clearly not all, samples from gold-bearing zones in all districts. About 30% of all wacke samples from known districts possess K_2O/Na_2O ratios greater than 1.0; 10 of 12 wacke samples with gold greater than 700 ppb have K_2O/Na_2O greater than 1.0 (5 of the 10 have K_2O/Na_2O greater than 2.0). Only 22% of slate samples from known gold districts possess K_2O/Na_2O ratios greater than 6.0; there is no clear relationship between anomalous K_2O/Na_2O values and gold contents in slate samples.

Work to date suggests that variations in the contents of SiO_2 and(or) CO_2 in rocks hosting gold-bearing veins cannot be consistently correlated with either hydrothermal alteration or gold mineralization. Less than 5% of wacke samples from known gold districts possess SiO_2/Al_2O_3 ratios greater than 8.0; all such 'anomalous' samples contain background contents of gold, sulphur and arsenic, as well as K_2O/Na_2O ratios of less than 1.0. No slate samples contain SiO_2/Al_2O_3 ratios greater than 5.0.

As noted previously (Kerswill, 1987), a predictive genetic model for Meguma gold deposits must not only account for the occurrence of much of the gold in early bedding-parallel (BP) crack-seal veins, but must also explain the apparently strong structural control on ore shoot distribution, as well as the presence of significant gold in late fissure veins. A multistage model that permits vein-controlled deposition of variable amounts of $SiO_2 \pm H_2O \pm CO_2 \pm S \pm As \pm Au \pm W \pm Sb \pm Cu \pm Pb \pm Zn$ from a succession of possibly quite different hydrothermal fluids that were generated at various stages during the structural and metamorphic evolution of the Meguma Terrane seems most appropriate. Mineralogical and chemical differences from one district to the next are controlled not only by contrasting host lithologies, but also by different histories of vein formation. Not all stages of veining (early BP, en echelon, true saddle reef, late discordant) occurred in all districts; different stages were not equally developed. Although much gold was deposited during formation of the early BP veins, much arsenic appears to have been introduced by later veins or structures (Kerswill, 1987). Abundant arsenopyrite is spatially associated with veins and structures that clearly post-date BP veins in most of the districts examined, but this relationship is particularly apparent in underground exposures at Tangier and Caribou. This could explain a lack of correlation between gold and arsenic in those districts in which most of the gold occurs in BP veins. The relationship between gold and hydrothermal alteration is similarly complex as much of the hydrothermal alteration also appears to have been generated by late events. The lack of a consistent relationship between gold and total sulphur in some districts may be related to the presence of mixed sulphur populations ('synsedimentary' sulphur deposited prior to vein formation and 'hydrothermal' sulphur introduced during vein formation).

Work to date confirms that several of the different stages of vein formation had the potential to deposit significant gold concentrations, and also suggests that each of the different stages may have produced a diagnostic geochemical and mineralogical signature in the host rock. Additional work is in progress to better document the latter possibility and to more clearly identify those chemical and mineralogical changes that were most closely linked to ore formation.

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CRACK-SEAL TEXTURE IN COLUMNAR-QUARTZ VEINS: IMPLICATIONS FOR FLUID PRESSURE, TIME OF VEIN FORMATION AND STRAIN PARTITIONING[1]

J. R. Henderson[2], M. N. Henderson[2] and T. O. Wright[3]

Numerous examples of episodic hydraulic fracturing and sealing have been documented for fibrous veins showing inclusion-band fabric since Ramsay (Nature, 1980) proposed the crack-seal mechanism of rock deformation. Here we describe an unusual solid-inclusion band fabric exhibited by isolated and dispersed 1-2 cm dia. columnar quartz crystals composing 10-20 cm wide bedding-parallel auriferous veins in the turbiditic flysch of the Cambro-Ordovician Meguma Group exposed within the Caribou Mine, Nova Scotia. The columnar crystals tend to be oriented normal to the vein walls and display Brazil twins. Viewed along the surface parallel to bedding, the crystals show hexagonal sections with dark-grey solid-inclusion rich centres and milky-white fluid-inclusion rich rims, forming an interlocking honeycomb fabric. Viewed in profile, the dark centres of quartz crystals are composed of clean quartz laminae bounded by white micas forming solid-inclusion bands. The 0.05-0.1 mm thick quartz laminae tend to be aligned parallel to the vein walls and terminate within large tapered crystals which have an outer zone of milky quartz.

These observations lead us to conclude that: (1) the solid-inclusion banded quartz resulted from episodic hydraulic fracturing and incremental growth of crystals dispersed in the fluid-filled fracture; (2) the crystals initially were attached to both walls of the fracture, but the tapered crystals indicate that subsequent fractures occurred antitaxially on their larger ends; (3) between pulses of hydraulic fracturing fluid pressure equaled lithostatic pressure, and the space between quartz crystals was occupied by an aqueous fluid; (4) the milky quartz displaced the fluid by growing in optical continuity with the solid-inclusion banded quartz, and (5) following vein formation, folding was accommodated by partitioning of strain between bedding-parallel shear in the wall rocks, and mainly rigid rotation of the veins which preserved their primary fabric.

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MECHANICS OF FORMATION OF GOLD-BEARING QUARTZ VEINS, NOVA SCOTIA[1]

J. R. Henderson[2], T. O. Wright[3] and M. N. Henderson[2]

Mawer (1987) described gold-bearing quartz veins in Meguma Group metagreywacke-slate beds as weakly deformed late-tectonic anticlinal saddle-reefs, resulting from a hydraulic-featuring mechanism proposed by Graves and Zentilli (1982). The anticlinal saddle-reef hypothesis for the origin of the bedding-concordant veins is not new: it was proposed for gold-bearing Meguma veins by Faribault (1899), and reiterated by Keppie (1976). Mawer's arguments for a late-tectonic origin for all bedding-concordant veins are inconsistent with our observations that many bedding-concordant veins formed early in the tectonic history of the Meguma Zone (Henderson, 1983; Henderson et al., 1986; Henderson and Henderson, 1986). Our data clearly show that most bedding-concordant veins (or bedding-parallel veins in our terminology) predate cleavage and folding in the host strata, and are not saddle-reefs.

Gold-bearing, bedding-concordant quartz veins in the Meguma Zone were described early in the mining history as 'barreled' veins (Silliman, 1864) in allusion to their tight folding. Dewatering of the Dr. Sutherland shaft at Moose River, Nova Scotia, in May 1988, gave us a chance to examine in place gold-bearing, bedding-concordant barreled quartz veins like those described from the days of active mining in the region (Rickard, 1912).

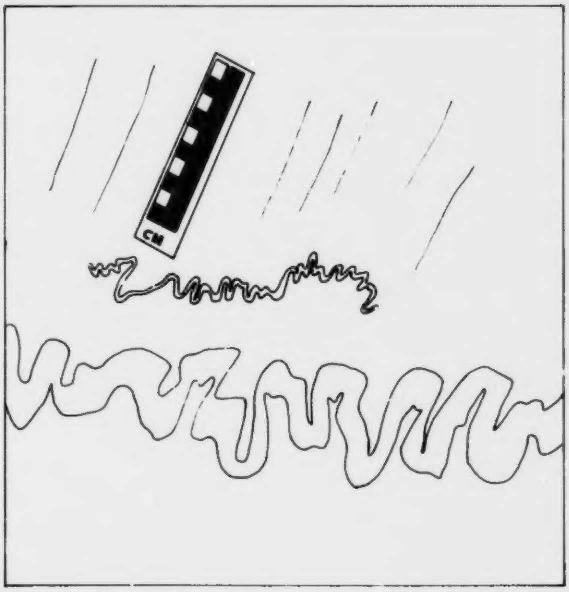

Figure 1. Bedding-concordant gold-bearing quartz veins on the crest of the Moose River Anticline. Scale divisions are in cm.

Figure 1 is a profile of a typical gold-bearing, bedding-concordant vein exposed in the Dr. Sutherland Mine, Moose River Mining District, Nova Scotia. In contradiction of Mawer's assertion that gold-bearing veins are weakly folded late-tectonic saddle-reefs, these veins show more than 60 per cent layer-parallel shortening, assuming a concentric buckle-folding mechanism. This strong shortening is not confined to major fold hinges; the gold-bearing bedding-concordant veins do not taper down-dip as Mawer claims, and are folded on the major fold limbs (Fig. 2). These recent observations

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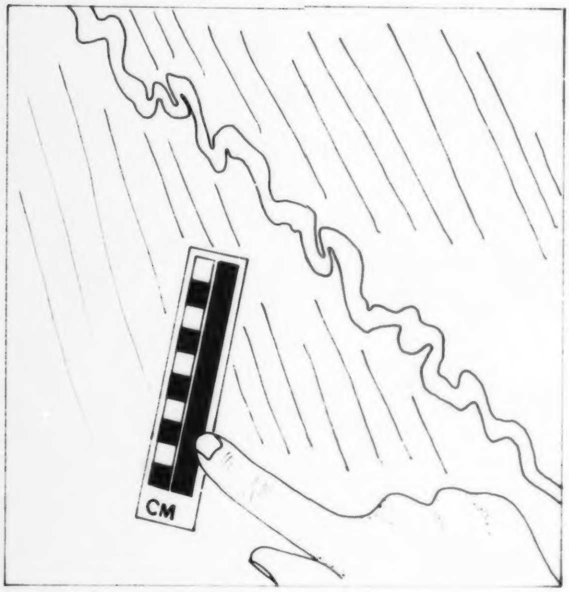

Figure 2. Bedding-concordant gold-bearing quartz vein on the limb of the Moose River Anticline.

are entirely consistent with published data (Henderson et al., 1986) that bedding-concordant veins formed in the Meguma strata before cleavage and folding, and underwent essentially the total tectonic strain recorded by other strain gauges in the rocks such as primary circular markers on the bedding surfaces and paleoplumblines in the beds.

Mawer's conclusion that gold-bearing bedding-concordant quartz veins are late-tectonic saddle-reefs restricted to the hinge areas of domical anticlines is incorrect, and is not a good exploration strategy as stated because it ignores early-tectonic gold mineralization (important in our view), and limits exploration to anticlinal hinge areas which have received considerable attention for over a century (e.g. Faribault, 1889).

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